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RESEARCH IN FARM STRUCTURES

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BY
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AN agricultural management which is changing rapidly to meet the demands for increased efficiency, requires the design and construction of farm buildings which will be most effective in increasing animal production and in preserving crops for the most advantageous marketing.

Buildings have not been fully appreciated as factors in production, and comparatively little research has been conducted on farm-building problems.

The wide distribution of comparatively small production units makes farm-conducted research impracticable, and requires the sponsoring of this important work by publicly supported research agencies.

The purpose of this survey has been to study the activities of these various agencies, to select the farm-structures problems on which investigation is most needed, and to formulate a program for nation-wide cooperation and coordination by means of which the desired information may be obtained most quickly and effectively.

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INTRODUCTION

The American farmer maintains a huge investment in buildings. Although not spectacular in nature, they exert a very definite influence upon agricultural welfare by influencing the costs of production, the preservation of farm products, and the standards of rural living. These factors are of sufficient importance to justify the application of the most advanced thought to the matter of farm-structures design. Nevertheless, workers responsible for the planning of farm buildings have been handicapped by lack of design data based upon adequate research.

This report presents the results of a study of the current situation in respect to farm-structures research. In addition to reporting the nature of the studies now under way, it presents some conclusions which have been developed and recommendations for a plan of action. Particular emphasis has been placed upon (1) results accomplished, (2) studies now being carried on, (3) present problems, and (4) policy or organization necessary to assure a more comprehensive research program and a better articulation of the activities of the various State experiment stations in the field of farm-structures research.

HISTORY OF THE PROJECT

For a number of years agricultural engineers engaged in farm-structures work have felt a need for closer cooperation and better co-

ordination of effort. A movement to this end took definite form when, early in 1927, a group met in Chicago to consider means of securing closer cooperation and a stronger farm-structures research program. At this meeting M. C. Betts, senior architect, Bureau of Agricultural Engineering, as chairman of a committee on research development in farm structures, was requested to compile (1) references to published material of value to research investigators in farm structures, (2) projects in farm-structures and related research in progress in State agricultural colleges and experiment stations, and (3) a list of suggested research problems relating to farm structures and equipment. These were prepared and distributed to such members of the American Society of Agricultural Engineers as were interested in farm structures.

At the annual meeting of that society in June, 1927, Swenehart (*31*)[3] questioned the economy of present construction methods. Betts (*1*, *3*), in reporting for the committee on research development, emphasized the present need for research and the lack of correlation of effort among workers geographically separated and without centralized leadership. At the meeting of the structures division of the American Society of Agricultural Engineers, in 1927, Strahan (*29*) analyzed the cost of milk production and showed that the income from scrub cows would not pay for any kind of housing, while high-producing cows require and justify a good barn. At the meeting of the same division in 1928, Cartwright (*6*), Strahan (*30*), Giese (*17*), and others emphasized further the need for careful study of the relationship between buildings and net agricultural returns, and for the formulation of a program of research by means of which the necessary information might be obtained. At that meeting the structures division adopted resolutions asking the Secretary of Agriculture to cause a survey to be made of the farm-structures research situation. Several of the land-grant colleges and universities had been engaged in farm-structures research, and had recognized a need for closer cooperation and correlation. Since the United States Department of Agriculture seemed to be the logical correlating agency, the Secretary was requested to consider the possibility of providing a research specialist whose work should be to make a survey of the research projects active at the various agencies interested in farm structure; to survey the present research facilities as regards both personnel and physical equipment; to prepare a comprehensive list of research projects relating to farm structures; to formulate a national program by means of which the work of the various institutions and agencies might be stimulated and coordinated; and to formulate a plan for the dissemination of the information obtained.

The substance of these resolutions was indorsed by several representatives of land-grant colleges and universities, and of industries interested in the farm-structures field. The Secretary of Agriculture accordingly authorized the organization of such a project, and invited certain organizations to participate by nominating representatives to sit as an advisory council.[4]

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[3] Italic numbers in parentheses refer to Bibliography, p. 51.

[4] The names of the organizations invited, and of their representatives on the council, are stated on third page of cover.

ORGANIZATION OF THE PROJECT

Henry Giese, of the agricultural engineering department of Iowa State College, was appointed to act as director of the survey for a period of 15 months beginning June 20, 1929. The council met in Washington, D. C., August 27, 1929, to discuss its own functions and to plan a program for the year's work. At this meeting the council agreed:

1. That farm-buildings design and construction have not received consideration in proportion to their influence upon agricultural production and agricultural welfare.
2. That proper solutions of the problems involved in the development of farm buildings would have far-reaching economic influence with respect to the investment in buildings and to production.
3. That investigations of the many problems relating to farm buildings should be instituted and carried on vigorously.
4. That the farmer's inability to conduct his own researches makes necessary the sponsoring of this work by publicly supported agencies.
5. That the past and present activities of such agencies have been generally inadequate and need stimulation and coordination.
6. That a properly conducted research program should clarify the farm-buildings situation, advance the science of agricultural engineering as it pertains to structures, stimulate resident teaching and extension work, and help standardize and simplify construction practice.

Upon these premises the director, under the guidance of the advisory council, undertook to study the present situation of research as it pertains to farm structures, to report the conditions as he found them, and to present a plan for stimulation and coordination by means of which the above objectives might be accomplished.

The council interpreted its duties to be: To act in an advisory capacity to the director of the survey, to suggest lines of activity to the director, to report to and stimulate activity among the constituencies represented on the council, and to submit to the Secretary of Agriculture a report with recommendations regarding matters of policy and a program for farm-structures research.

THE SURVEY

It is scarcely possible to evaluate, in more than a very general way, the relative importance of individual research activities included in a group. The farm-structures field touches widely divergent interests, and what seems vital to one group may seem less important to another. What can be done to encourage more and better research along the lines already recognized as important? How can cooperation and coordination of effort be effected?

With these problems in mind, the director visited as many institutions and persons as seemed practicable in the time allowed for the survey. These included land-grant colleges and universities, certain Federal agencies, commercial organizations, trade associations, and conventions of technical groups. In short, effort was made to obtain the views of as many qualified persons as possible, whether in the

educational or the commercial field, who are interested in the design, construction, equipment, or use of farm buildings.

During the progress of the survey the director visited 28 land-grant institutions and interviewed 205 staff members. These included 4 college presidents, 21 directors and vice directors of experiment stations, 20 agricultural-college deans, 7 engineering-college deans, 87 staff members of agricultural engineering departments, 2 agronomists and farm-crop specialists, 30 animal and dairy husbandmen, 10 agricultural economists and farm-management workers, 9 horticulturists and foresters, 9 poultrymen, and 6 home-economics workers.

The director also called upon 30 industrial organizations having interest in materials or equipment for farm buildings. At these commercial plants 73 officials were interviewed, including 6 presidents, 4 vice presidents, 14 general and sales managers, 31 engineers and directors of research, 3 advertising managers, and 15 trade-association officials. The director attended 11 conventions of workers interested in farm buildings. Numerous other conferences were held with Government research workers and others interested in the development of research programs in farm structures. The report which follows is based largely upon the information obtained in these conferences.

Those directly responsible for building design have shown an eagerness for more reliable information, and have recognized their handicaps in attempting to cover such a large field alone. Other subject-matter workers, while interested, have on the whole given little serious thought to buildings problems. A definite and growing desire for closer relationship in the solution of common problems was noted among the individual States. Self-sufficiency is rapidly passing and individual workers realize more and more the necessity for pooling of efforts.

THE PRESENT SITUATION

A few workers who for a number of years have been actively engaged in conducting and promoting farm-structures research, have accomplished much. Their work, however, has not been adequately supported and the extent of effort not in keeping with the needs of an industry in which is involved an investment of nearly $12,000,000,000.

THE NEED FOR RESEARCH

According to the 1925 census, the total investment in farm buildings in the United States is $11,746,629,000. The investment in each of eight States exceeds $500,000,000. (Fig. 1.) Land is the only larger item of investment on the farm. While accurate figures are not available, it is conservatively estimated that American farmers spend several millions of dollars daily upon the construction and repair of buildings. The annual farm fire loss is more than $100,000,000 and to this economic loss must be added a yearly loss of 3,500 lives. Fire losses are truly economic losses and in the majority of cases are preventable. Repairs become necessary to take care of wear or the ravages of destructive agencies such as temperature, moisture, wind, and insects. Good farm management frequently involves remodeling of buildings.

Farm buildings definitely influence agricultural welfare. Aside from the fact that beauty and harmony add to the pleasure of living and incidentally influence the production of the worker, there is a close relationship between buildings and the production cost of farm products.

Buildings definitely affect animal production. Stable temperatures influence milk flow and feed consumption. Conditions within the barn affect the quality of milk and ultimately its market price. Many cities now are regulating the conditions under which milk is produced, in an attempt to prevent disease and secure a better

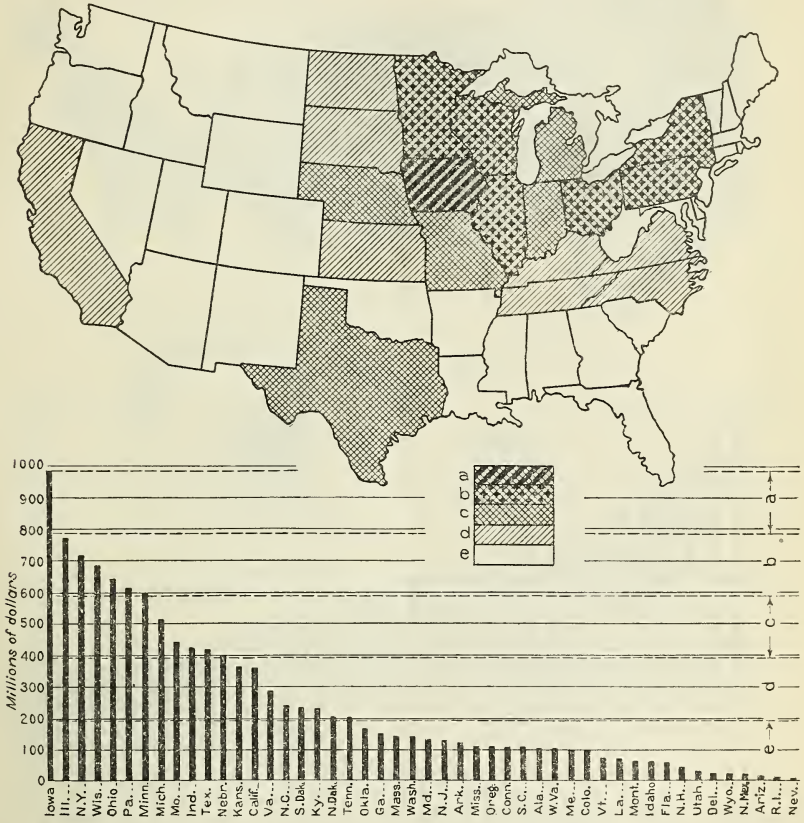

FIGURE 1.—Investment in farm buildings, 1925

product, though some of the provisions in control codes have not been thoroughly investigated. Buildings also exert a measurable influence upon the labor of management and other production factors.

Egg production and bird comfort go together, and poultry housing occupies a position in production similar to that of dairy housing.

Buildings are important factors in the conservation of farm products. Grains are conditioned and preserved by careful housing. Recent harvesting methods have brought with them new problems

in handling, processing, and curing. Market conditions, lack of adequate transportation facilities, and farm feeding often make farm storage desirable or necessary. The difference in grade as between well-stored and poorly stored grain is often appreciable. Fresh vegetables and fruits now are deemed necessary items in our everyday diet. A few years ago it was difficult, if not impossible, to secure them except at certain seasons. Better storage methods have made possible the extension of the marketing period, with benefit both to the producer and to the consumer. In the past, large shrink-

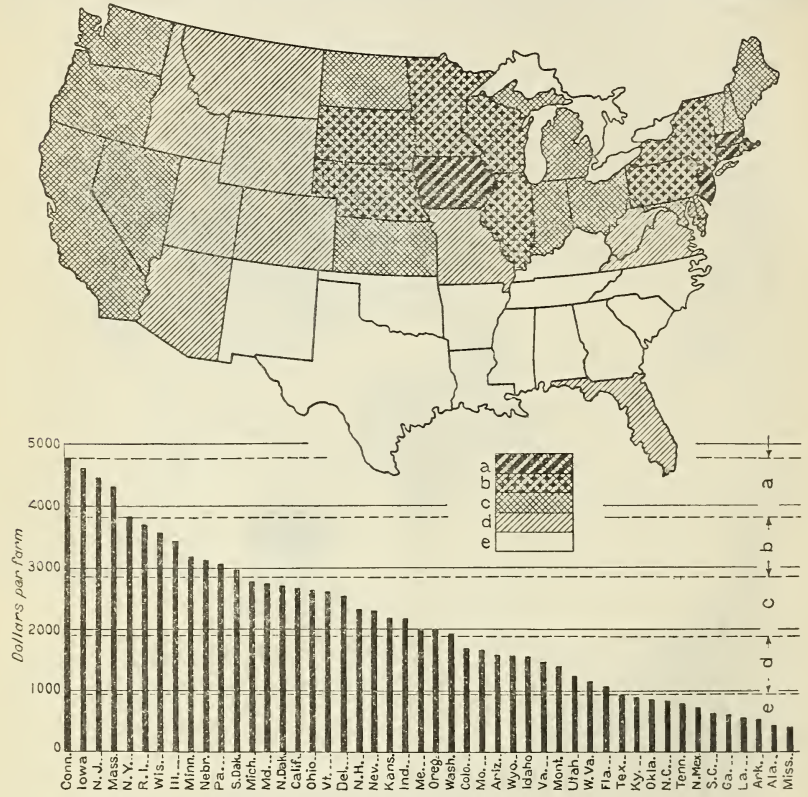

FIGURE 2.—Investment in farm buildings in dollars per farm, 1925

ages have been accepted as necessary. While storage methods have been improved, the research opportunities in this field are still large. Efficient and well-arranged structures help to reduce the troublesome problem of labor overload at harvest time.

Adequate, well-planned buildings and pleasant surroundings induce pride and contentment and assist in retaining satisfactory hired help.

The farmstead should be considered as a production unit and buildings should be carefully planned to fit into an efficient farm-management program.

According to the 1925 census there are in the United States more than 6,250,000 farm units, but the average investment is relatively small. (Figs. 2 and 3.) The individual farmer's interest in farm structures research is lessened by the long period of service generally obtained from his buildings. Not every generation builds a barn. In many cases, especially where materials have been readily available, buildings have been so substantially built as to last several generations and consequently remodeling to meet service requirements is a more acute problem than new construction.

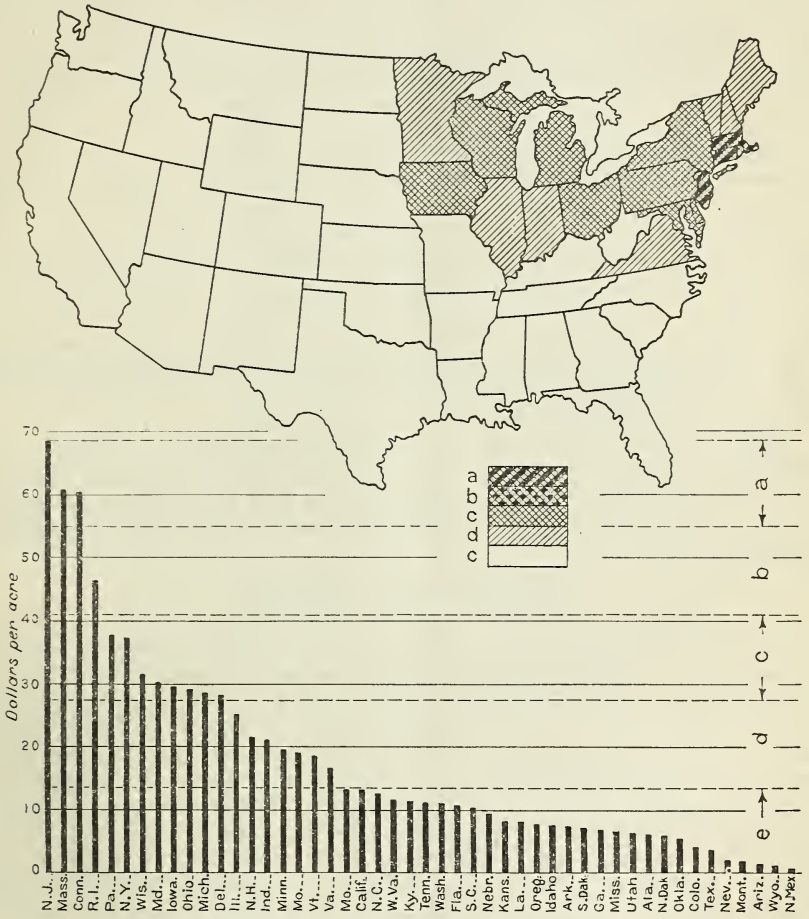

FIGURE 3.—Investment in farm buildings in dollars per acre, 1925

Under present methods of merchandising the farmer does not buy buildings complete and ready for operation as he buys other equipment. He buys partially fabricated materials or builds from materials produced on his own farm. In either case skillful handling on the part of the purchaser is required. As construction specialists are not usually available, the buildings frequently are unsuited for

their intended use and are not constructed in a way that will tend to reduce depreciation and repair costs to a minimum. The situation is altogether different from that in cities, where buildings generally are planned by trained architects, built by experienced contractors, and checked by building inspectors.

Proper construction of buildings necessitates a careful study of building methods. The requirements as to space and sanitation, and the conditions of air temperature, relative humidity, and rate of air movement, must be known before buildings can be well designed, and in meeting these requirements materials and labor must be used economically. New materials should be adapted to farm uses. Development of standard practices and simplification of construction methods would aid materially in securing better buildings. Much of the data now available for the design of farm buildings are based on tradition and probably are inaccurate.

The architectural profession in general has not as yet shown interest in developing farm structures. The small, scattered units have not proved profitable from a professional standpoint, and the architect has not seen the necessity for specific training in the design of farm buildings. The farmer usually does not employ professional service, because he does not appreciate the importance of scientific design and is not convinced of the value of the assistance for which a professional charge is made. On the other hand he may be reluctant to accept recommendations from organizations that give free assistance in planning but that expect eventually to sell enough merchandise to cover their service costs.

There is, then, a real need for constructive effort in research. To state this need, however, is not sufficient. The attempt has been made in this study to fix the responsibility and to outline a program which may be expected to assure adequate consideration of these problems.

RESEARCH NOW IN PROGRESS

From the following list of active farm-structures projects it will be noted that more than 50 are in progress at 20 stations. Six States —Arkansas, California, Illinois, Missouri, Virginia, and West Virginia—report activity in the formulation of designs for farm buildings. Georgia, Idaho, Indiana, Iowa, Michigan, Minnesota, New Jersey, New York, and Ohio report projects relating to the ventilation and temperature control of animal shelters. Georgia, Indiana, Iowa, Kansas, Massachusetts, New York, North Dakota, Ohio, Virginia, and West Virginia are conducting studies relating to storage of crops. Arkansas, Idaho, Iowa, Kansas, Minnesota, Missouri, and South Dakota have projects on structural design and the proper treatment and use of materials. Missouri is studying the economic value of buildings. Kansas and New York are investigating sewage disposal. In addition, Iowa reports projects on silo capacity and on the harvesting and storage of ice. New York and New Hampshire are studying the precooling and storage of milk.

ACTIVE FARM-STRUCTURES PROJECTS (MARCH, 1930)

Arkansas	Farm buildings (plan service).
	Preservation of posts.
California	Barn equipment for livestock in California.
	Adobe construction.
	Farm sewage disposal.
	Farm fencing.
	Poultry housing.
Georgia	Temperature study in poultry house design.
	Control of ventilation and heat in the curing of sweet potatoes.
Idaho	A study of building requirements for poultry production in Idaho.
	The development of a method for structurally testing farm buildings.
Illinois	Building planning.
Indiana	Apple storage.
	Poultry houses—influence of insulation and artificial heat.
Iowa	Treatment to make masonry silo walls impervious.
	Silo capacity.
	All-masonry barn.
	Prepared roofing.
	Masonry water tanks.
	Harvesting and storage of ice.
	Efficiency of barn-ventilation systems.
	Dairy barns and equipment.
	Air requirements of poultry.
	Storage of corn in Iowa.
Kansas	Effect of the method of storing wheat upon quality.
	Harvesting and storage of grain sorghums.
	Deterioration of concrete silos.
	Sewage disposal.
	The design of the farm house (department of architecture).
Massachusetts	Investigation of apple storages.
Michigan	Dairy-barn ventilation.
Minnesota	Ventilation studies on gravity and fan ventilation. Investigations of farm buildings: Materials, paint tests, temperatures in structural tile poultry houses, storage of ice in pits.
Missouri	The relation between investment in buildings and fixed equipment and earning value of land.
	The design of buildings and equipment.
	Prolonging the life of fence posts.
New Hampshire	Precooling and storage of milk.
New Jersey	Poultry-house ventilation.
New York	Potato storages.
	Electric refrigeration and milk-cooling tanks.
	Dairy-stable ventilation.
	Septic tank design.
	Poultry-house ventilation.
	Ventilation for seed drying.
North Dakota	Ventilated bin studies.
Ohio	Soft-corn storage.
	Heating poultry house floors.
South Dakota	Rammed earth construction.
Virginia	Farm-building plans and equipment.
	Investigation of common storage for apples.
	Mechanical refrigeration for small dairies.
	The Virginia farm home.
West Virginia	Farm-building plans and equipment.

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The mere listing of projects gives no adequate idea of the effort represented. In some cases the work is being exceptionally well handled and gives promise of results of real value to the engineer in designing buildings. In other cases the work has been well begun but needs stimulus by the supplementing of funds or of personnel in order to make it increasingly effective. Some unnecessary duplication occurs where several stations are working on similar projects. Some long-time projects are being carried on the active list, whereas little or no work has been done on them for years; manifestly these should be either revived or dropped. In still other cases the projects are inadequate, poorly organized, insufficiently supported, and do not give promise of benefit to agriculture. The carrying of such projects detracts from the dignity of farm-structures research and materially lessens the probability of increased support.

DIFFICULTIES OF RESEARCH IN FARM STRUCTURES

The conditions pointed out above are to be expected in view of the present lack of coordination among structures-research workers. With research agencies working independently, it is scarcely reasonable to expect a high degree of correlation; duplications will occur, as also the failure to take up worthy projects owing to insufficiency of funds. Meanwhile, effective design is hampered by a lack of standardization of housing requirements. The large variety of available plans for the same type of structure, in which are marked differences, testifies to the fact that much of our data are still in the realm of opinion.

Few farm-structures problems are local in character. While one State may be a principal producer of an agricultural commodity, usually a considerable number of States produce that commodity to an extent which justifies an interest in housing problems relating to it. From Figures 4 to 12 it will readily be seen that even in the production of tobacco, apples, and hogs—which are comparatively localized—and much more in dairying and poultry raising, the problems of housing any one of the principal kinds of crop or stock are not limited to one State, nor does the character of these problems change at State boundaries. Variations in housing practice can be justified only on the basis of climatic differences. The group of States interested in potato storage has a problem which does not greatly concern that group which has a corn-storage problem.

Coordination of effort among the States in which a particular problem is acute would materially increase effectiveness in the solution of housing problems. No State can carry on a research program so comprehensive as to include concurrently all its farm-building problems, but it would seem that each State might enter wholeheartedly upon a program involving thorough study of a few problems that were part of a national program if the other problems were being adequately investigated elsewhere. A program of this kind requires an understanding among the States; there must be cooperation. The very nature of agricultural engineering as an applied science demands also a close relationship with subject-matter specialists in other lines.

Many individuals and organizations are, or should be, interested in farm-building problems. Of these the farmer is first as he lives in and works with the buildings. Then there are the Federal Department of Agriculture and the corresponding State organizations in the land-grant colleges and universities. Within these organizations are research workers and resident and extension teachers who specialize in such lines as agricultural education, agricultural engineering, animal husbandry, dairy husbandry and industry, economics and farm management, farm crops, home economics, horticulture, plant pathology, and veterinary medicine. In addition there are the State departments that have responsibility for the control of housing as it may affect human health and safety. Manufacturers of structural materials and building equipment must know the service requirements, the suitability of their products, and the proper specifications for selection and fabrication, if they are to pursue an effective long-time policy.

While these large groups should be intensely interested in farm-structures problems, the interest in many cases is, as a matter of fact, secondary to that in subjects that are really less important. Farm buildings are not spectacular and their influence upon agricultural returns is not as apparent as are some other factors. The cost of a building is quite evident while the returns which it brings are sometimes not so apparent. The entire cost of a building must be met at one time and is likely to seem larger than the cost of feed, for example, which is several times as large when considered on a basis of annual charges. Operations that occur annually usually attract more interest than those which may occur only once in a generation or even less frequently. Resources for farm-structures research effort are limited because other problems have seemed more acute and have received the available support. Buildings have not been analyzed in their true relation as production factors. Moreover, the human tendency is to give first attention to the simpler and more clear-cut problems and to those in the solution of which outside cooperation is less essential.

The opinion has been expressed that buildings do not add to the sale value of farm property in proportion to their cost, and that a farmer can not afford to hazard his investment. This view is not sound, in that the relation to operation should be the vital consideration. Wiecking (*35*, *p. 34–37*) states, after study of some 600 midwestern farms, that within limits the buildings actually enhanced the sale value of the farm property above their depreciated value. Each increase in average value of buildings up to a total of about $25 per acre added more than a like amount to the sales value of the farm, though beyond this point apparently each increment in buildings value added less than the same amount to the sales value. From Wiecking's observations, it would appear that one might reasonably expect, in the mid-West, to realize at a sale full value on a set of farm buildings valued up to approximately $48 per acre, which is nearly twice the 1925 census valuation in the mid-West. Farm buildings ordinarily are built, however, not for their sale value but for their value in increasing or holding the value of the farm products or in lowering the cost of production. Emphasis is laid here upon the necessity for a study of buildings upon the basis of their influence upon farm-production costs.

Building problems have not shown the challenge necessary to enlist sufficient support of station directors and others administering funds for research. With a constant demand for building plans, and limited resources for handling this demand, the tendency has been for the workers to attack the problems from the construction standpoint without an understanding of the economic relationships and the service requirements. This is not an indictment of the splendid efforts which have been made under great handicaps; it is rather a plea for more fundamental analyses of structures problems and more convincing presentation which will command the attention of those who hold the purse strings. Structures research should be based upon the need of basic information and this need should be presented in the form of well analyzed and clearly stated subjects having obvious appeal.

Experiment station directors have emphasized the personal side of research and their willingness to support workers who show results. Farm-structures research is comparatively a new subject; it has not become well established and there has been no large demand for trained workers. Industry and the colleges have employed students in farm structures directly upon graduation, and there has not been sufficient incentive for them to seek or acquire further training in research methods. Moreover, deans and directors have been definitely trained in the technique of research in older, better-established lines and there are sound reasons why appropriations for experiment-station work should be allotted in considerable part to lines of investigation that already have shown outstanding results. Research fellowships and a wider knowledge of the opportunities in farm-structures work will assist in interesting capable young men to prepare themselves for research careers in this subject.

The foregoing discussion of the difficulties of research in farm structures may be summarized in three chief reasons for the present rather unsatisfactory status:

1. Interest in structures, on the part of agricultural research groups and workers is in many cases secondary to that in other subjects. This attitude arises largely from an inadequate conception of the function of structures in the economic scheme of farming.
2. Problems of personnel.
3. Lack of a nation-wide policy of correlation of research in farm structures.

BUILDING PROBLEMS IN THE AGRICULTURAL INDUSTRY

It is rather generally conceded that farm-building construction has been at low ebb. Wood (*36*), without taking account of small buildings such as portable brooder houses, portable hog houses, or of small stationary structures, and without examining interiors for needed repairs or remodeling, concludes that in Nebraska—

1. Little remodeling or repairing is being done at the present time, nor has much been done for a period of at least 10 years.
2. On 20 per cent of the farmsteads, no replacement, repair, or painting was necessary, yet of the 14,494 buildings checked 14.58 per cent needed some repair and 5,939 or 40.9 per cent needed painting badly.

3. A conservative estimate of the replacement, remodeling, and repair costs alone would be $400 per farm, of which at least $200 would go for building materials.

4. While few machine sheds were seen, practically every farm had a garage which was the newest and best-kept building on the place.

While the above remarks are based upon observation, opinions of men in other States would seem to indicate that conditions elsewhere do not differ materially from those in Nebraska.

On the other hand, the New Breeders' Gazette states [5] that farmers in 17 mid-continent States spent more than $1,500,000,000 in new building construction in 1927, and nearly $500,000,000 for remodeling and repairs. Construction in 1928 was estimated to be nearly as great. The National Lumber Manufacturers' Association advertises [6] that "each year farmers buy half a billion dollars worth of lumber." Considering that native materials are frequently used, that many buildings are constructed partly or wholly of materials other than wood, and that labor constitutes a large part of the cost of a new building, it is evident that the present farm construction bill is, in the aggregate, a large item.

Much farm construction is ill-advised and consequently is short-lived or does not meet the service requirements. Replacements and repairs then become unnecessarily high. Since the deflation in land values a decade ago, farmers have been scanning their expenditures to see where reductions could be made. The costs of construction and repair of buildings have seemed too often to offer the best if not the only opportunity for keeping down expenses; hence there has been a cry for cheaper construction. In many cases existing buildings have been allowed to deteriorate, and in some instances have actually been robbed of materials for use in emergency construction. These tendencies, with due allowance for economic pressure in some instances, indicate that the true service of buildings has not been appreciated.

Other complications in a program of farm-building design result from changes in agricultural management. The rapid development of machine methods in production has necessitated modifications in building construction. Evidence of this is found in the tendency toward larger farm units. Changes in highways, transportation methods, and markets may make the original site of the farmstead unsuitable. The buildings themselves may not be adapted to present production methods. Efficient handling and storage are just as essential as efficient cultivation and harvesting. These changes in management and the consequent necessity of remodeling available buildings, place upon the agricultural engineer the responsibility of anticipating future requirements so far as possible, and of designing building units that can be adapted to changes in agricultural practices without material increase in cost.

Housing constitutes but a minor factor in the cost of production but it frequently exerts a major influence upon production and preservation. Strahan (*29*) has attempted to evaluate the various cost factors in the production of milk. This valuable piece of pioneer-

[5] A SURVEY OF THE FARM-BUILDING SITUATION. 1928. [Mimeographed.]
[6] Agr. Engin., July, 1929.

ing should be checked, and similar studies should be made in the other lines of agricultural production. When due consideration is given to the fact that in the original analysis the storage of feed and the housing of young stock are double-charged, the relative values of the various factors for a cow producing 9,000 pounds of milk per year become approximately as follows: Use of animal, including interest and depreciation 17.5 per cent; hauling of milk, 3.5 per cent; labor, 20.0 per cent; feed, 52.5 per cent; rental of building space, 6.5 per cent. These are average figures; for individual cases the records might vary considerably. Even so, it can be seen that the charge for good housing is relatively small. It is further quite obvious that lowering the original cost of a barn will decrease the cost of producing milk very little.

Present data, which are meager and which should be supplemented by further study, show that indiscriminately to cheapen construction might actually increase the total production cost by increasing other factors more than the saving made on the building. White (*34*) found, in his study of chore routes in dairy barns, that the average route distance per stall was 35.3 feet for a face-in barn and 45.6 feet for a barn with crosswise rows, an increase of nearly 30 per cent. Labor is a considerable factor in the cost of dairying. A 25 per cent reduction in this item would absorb almost the total cost of rental of building space. Armsby (*2, p. 348*) showed that a cow is sensitive to environmental temperatures, and that below certain limits heavier feeding is necessary if body temperature and production are to be maintained. He states:

> * * * It appears that a ration sufficient for maintenance at a temperature higher than the critical may be insufficient for maintenance when the thermal surroundings are lower than the critical because of the failure to meet the demand for heat. What the critical temperatures of the different farm animals are is therefore a question not only of physiological but also of economic significance.

Walter G. Ward reported that the majority of farmers answering a dairy-barn questionnaire, circulated by the American Society of Agricultural Engineers, recognize a drop in milk flow resulting from unfavorable stable temperatures. This drop is not temporary but usually continues throughout the current lactation period. The exact conditions necessary to effect this drop and the extent of the drop are at present not known, but should be carefully investigated.

The constantly increasing number of cities which place definite restrictions upon the construction of buildings used for the production of dairy products, and the activities of the United States Public Health Service are evidence of a general belief that buildings exert an influence upon the quality of milk produced and the lack of uniformity of these codes shows that the exact relationships are still unknown.

From the foregoing it is evident that dairy housing influences labor and feed consumption, as well as quantity and quality of product. Efficient farm production depends upon the correct application of these principles by the individual dairyman. Farming is carried on in many scattered units and much of the money spent for buildings is not well spent. The farmer buys semifabricated mate-

rials; if he is to use these well, he must have assistance. This responsibility obviously falls to the publicly supported land-grant colleges and universities and the Federal Government.

The farmer's recognition of his dependence in this respect is evidenced by frequent requests for information. In 1927 the Iowa Experiment Station (*4*) circulated 30,000 sheets of farm-building plans to farmers. Other States and the United States Department of Agriculture have had a similar experience. In March, 1930, the Federal department received 336 requests from 45 States for information concerning farm buildings. These numerous requests are evidence of the need for adequate plans and other information, and that the farmer will take advantage of what is available.

These service demands show also a real opportunity for leadership in the farm-buildings field. At the same time they have caused some embarrassment to the agricultural engineer and actually may have retarded research by diverting his time. In some stations where only one man's time, or less, is available for farm-buildings work, it is so completely occupied by class work, answering correspondence, and preparation of building plans, that little or no research is accomplished. Moreover, the lack of definite and accurate information has made difficult the response to service demands.

As Walker (*33*) has stated in regard to farm-machinery research, the objective of farm-structures research is not buildings, but agriculture. The real farm-buildings problem is the design and construction of buildings that will lower production costs and raise living standards. This may mean the developing of methods of construction that will enable each unit to be built more cheaply, or it may mean that for reducing total production costs through more efficient management the present building standards should be maintained or even raised. Buildings should be considered as tools in the farm industry—a means and not an end—and their suitability with regard to their respective functions should be determined. This can be accomplished only through a research program conducted on a parity with those in other lines of industry and in keeping with the economic importance of buildings in agriculture.

A TYPE ANALYSIS FOR FARM BUILDING RESEARCH

In general, farm buildings may be classified as animal shelters, crop storages, and miscellaneous structures. Animal shelters include such buildings as dairy barns, hog houses, poultry houses, horse barns, beef cattle barns, and sheep barns. Crop storages include grain bins, corn cribs, vegetable cellars and silos. The miscellaneous structures include, for example, dwellings, machine sheds, smoke houses, and fences. Some buildings may serve a joint purpose and be included in two or even all three classes.

As has already been mentioned, the first step in a study of a farm building should be to determine its economic relationships. The second step should be to determine the service requirements of the livestock or products housed. The third step has to do with the use of materials in providing these requirements. A more detailed analysis follows.

The relation between buildings and farm production costs:

An analysis of the various cost factors in production.
A study of the influence which buildings may exert upon other production factors—
Labor or management.
Feed consumption.
Productive life of animals.
Quantity of production.
Quality of product.
Preservation of products.
Orderly marketing and the benefits to be derived therefrom.
Building overhead which can be justified.

The requirements imposed upon the buildings by the animals or crops to be housed:

Space.
Optimum values of environmental factors. (Heat, light, ventilation, etc.)
Protection against pests and other destructive agencies.
Loads.

The technique of construction:

Efficient designing.
Careful selection of materials.
Correct and economical use of labor and materials.
Control of environmental factors.

As has been stated, buildings for a farm should be considered from the same standpoint as buildings for any other production enterprise. The cost per unit of production (i. e., per quart of milk, per egg, etc.) is a much more important consideration than is the original cost of the building. Depreciation and upkeep can not be ignored. An architect, designing a manufacturing plant, must know the service requirements as well as the approximate expenditure justifiable. The agricultural engineer has endeavored to design farm buildings without authentic data. In some cases obtaining these data is not strictly a responsibility of the engineer, although his assistance may be valuable to other subject-matter workers in establishing and maintaining technical control. In all problems that require more than one specialist, close cooperation is essential for satisfactory results. There is a growing tendency toward cooperative projects. Many problems are so complex that no one worker has sufficient training and experience to handle all their phases. In determining the relation of farm buildings to agricultural production and in determining service requirements, the agricultural engineer may find it expedient to play a relatively minor part, in order to obtain the design data so necessary for an adequate solution of the technique of construction, which is preeminently an engineering responsibility. Until these data are obtained, the design of farm buildings will always be largely a cut-and-try procedure—one that is not characteristic of engineering and that will not command the respect of those holding the purse strings.

The basic needs of farm-structures research are the analysis of the relation of the buildings to agricultural management, and the determination of the services that must be provided if efficient production or conservation is to be achieved. For animal shelters the important service problems relate to the maintenance of conditions which will facilitate production. What are the comfort zones analogous to those developed for human beings by the American Society of Heating and Ventilating Engineers? For crop storages, preservation is the prime consideration. In many sections of the country only

one crop can be grown annually, but satisfaction of the needs for that crop requires storage which will maintain the product in marketable condition.

The details of construction must be analyzed. The requirements of service buildings on the farm differ from those of some other structures, in that the desirability for variation in design either does not exist at all or it exists to a less extent. By standardizing construction, one's efforts in designing a barn or a grain-storage building may be so multiplied that the cost per unit is small.

How can the building be constructed with the greatest economy of labor and materials? What standards should be maintained in the use of materials? What materials are most suitable for certain uses, and what treatment is necessary or advisable? New materials are constantly appearing; can these be used to advantage in farm building construction? Have we fully developed the uses of materials now available? Without question, upkeep on farm buildings is unnecessarily high and is due, in many cases, to the improper use of materials. What are the weak points in present construction? How can methods of fastening be improved in order to develop the full strength of the materials? What are the loads imposed upon the building by the product housed? What provision should be made to resist wind, fire, lightning, insect pests, or other destructive agencies? These are some of the pressing problems in construction technique. A farm-building code is badly needed.

The following analyses, which are by no means complete, are given to indicate the general nature of problems for several types of housing. Some of these have been discussed by Trullinger (*32*).

DAIRY HOUSING

With the possible exception of the farm dwelling, the dairy housing is more a national problem than is any other type of farm structure. Dairying is an important industry in nearly every State in the Union. (Fig. 4.) The Secretary of Agriculture, Mr. Hyde, in an address before the National Cooperative Milk Producers' Association in 1929, said "the value of the raw material furnished by the humble dairy cow and of the products derived therefrom exceeds the value of the production of any other industry." He stated, further, that the dairy industry in 1928 produced milk weighing twice as much as the pig iron produced in the United States; that the dairy industry's products are not greatly exceeded in value by that of the country's cotton and wheat combined; that the dairy industry accounts for about one-sixth of the gross income of all agricultural pursuits, including both livestock and crops.

The importance of housing has been more generally recognized in dairying than in any other agricultural enterprise. Dairy housing is definitely related to human health and is now regulated by law in many sections. The adoption of control codes is spreading rapidly. Ordinances are based largely on opinion, however, and there are many unsolved problems. The economy of well-constructed barns has been questioned, yet better construction may materially lower the costs of other factors entering into milk production.

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Climatic differences require certain variations in building construction and management. In the more severe climates it is desirable to provide walls, ceilings, and roofs with low heat-transmission coefficients and ample provision must be made for feed storage. The character of the market may influence some construction details; for instance, production for a condensary or a cheese factory may not require the exacting care in some details that is demanded of the producer of milk for raw consumption. The environmental conditions necessary for efficient production must be

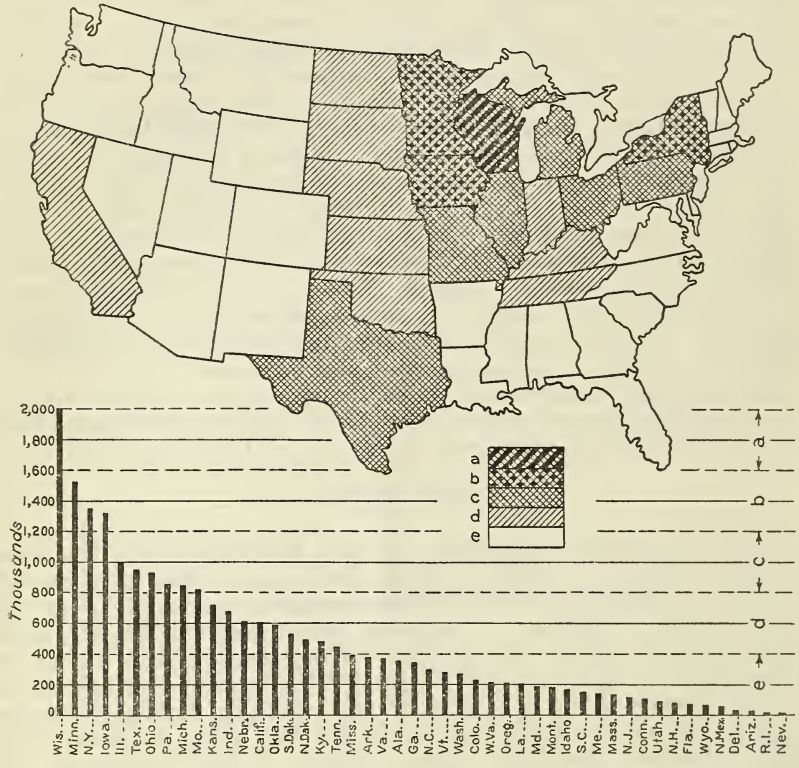

FIGURE 4.—Milch cows and heifers on farms, by States, 5-year average (1925–1929)

established for the entire country, but the accomplishment of these conditions in the various climatic belts is a matter of engineering design. When the economic relationships and the service requirements have been determined, improvement in design may be undertaken.

The present variations in the recommendations of various States are confusing. A standardized and simplified practice would result in better construction, lowered original cost, and slower depreciation. The following partial list of dairy-housing problems indicates the magnitude of this one phase of housing.

ECONOMICS

How much building overhead is justified on a dairy farm?
How does the arrangement of buildings in a farmstead affect the operating charges?
What proportion of the total cost of producing milk is chargeable to the use of the building, and how much influence may the building have upon labor charge, cost of feed, health and productive life of stock and quality and quantity of product?
Do barns depreciate more from obsolescence or from deterioration? (This is of interest as affecting the substantiality required for barn construction.)
How will probable changes in management (e. g. chopping and drying of hay) affect barn construction?

FUNDAMENTAL REQUIREMENTS

Does the lighting of the dairy barn affect the likelihood of cleanly milking practices? If so, what concentration should be required by ordinance, particularly for the highest grade of milk, and what greater concentration, if any, should be recommended?
Does adequate room per stanchion, thus avoiding overcrowding, tend toward cleanly milking practices? If so, what amount of air space per stanchion should be required by ordinance, particularly for the highest grade of milk, and what greater air space, if any, should be recommended in the case of reconstruction and new construction?
Does the ventilation of dairy barns affect the health of cows, and therefore the quality or quantity of the milk? What are the optimum standards for the various ventilation factors?
Does the construction of dairy barn floors tend toward cleanly milking practices or a greater quantity of milk produced per cow? If so, what kind or kinds of floor should be required by ordinance, particularly for the highest grade of milk?
Does the construction of the floors, walls, and ceilings of milk rooms lead to more cleanly milk-house practices, to the extent that the surfaces of these parts are of such construction as to be readily cleaned? If so, what requirements should be made by ordinance for the highest grade of milk?
Does screening of the milk room affect the likelihood of disease transmission through milk, and should screening be required by ordinance, particularly for the highest grade of milk?
Does sanitation of the privy have a bearing upon the transmission of disease through milk? If so, how should the privy be constructed to make it sanitary?
Does sanitation of farm water supply have a bearing upon disease transmission through milk? If so, how should the farm water supply be handled to remove this danger?
What is the most economical and effective type of construction of steam sterilizing chambers?
How should the thermometers of sterilizing chambers be installed so as to be certain to give a dependable temperature reading?
What is the best material and form of construction for a chlorine-solution disinfection vat for disinfecting cans, pails, and crates of bottles?
How can present common methods of stanchioning cows be changed so as to reduce labor and house more animals in a given barn?
How can the barn be arranged so as to reduce to a minimum the labor of management?
How can the heat of outgoing air (including heat of vaporization and fusion in water vapor) be used to warm incoming air?
What are the principles governing condensation of moisture on stable walls as regards conductivity of wall material, surface coefficients of wall material, humidity and dew point of air near wall, and rate of air movement past wall?
How can the temperatures in dairy barns be controlled effectively and economically?
How much moisture is permissible in animal shelters and how can the excess be removed effectively and economically?
What is the critical temperature of the dairy cow? The comfort zone?

What is the normal metabolism of the cow under conditions of maximum production and how much can this be increased without loss of efficiency?
What are the relative merits of gravity and mechanical ventilation for farm buildings?
What is the best method of controlling temperature for dairy barns in the warmer climates?
What is the relation of heat-transmission coefficients as determined for laboratory test units of small area, to those for large areas represented in completed buildings?
What heat-transmission coefficients are necessary for walls of dairy barns in the various climatic belts?
Can dairy wastes be run through a septic tank with impunity?
For what magnitude and distribution of wind loads should barn-roof trusses be designed?
Would glass substitutes admitting ultra-violet rays be beneficial in the dairy barn?
What constitutes a draft? (A draft is usually considered undesirable in the ventilation of animal shelters.)
What are the managerial factors that would influence barn design? For example, should cows be kept in their stanchions overnight? Through what range of outside temperatures may cows be allowed outside? Is appetite stimulated by exercise? Should the bull pen be included in the dairy barn proper?
Can two-story barns be made sufficiently dust-tight for all practical purposes?
What temperature of drinking water will stimulate greatest consumption?
What metals will prove most resistant to rust when in proximity to dairy barn wastes? (Stall partitions rust out rather quickly where they enter the stable floor.)
What are the possibilities of increased use of mechanical equipment to reduce the labor costs in feeding, milking, processing, or cleaning? (Endless conveyor, belts, or drags, might be used in a trough to deliver feed, etc.)
Should dairy roughage be stored on floors above the animals or on the ground in adjacent buildings?

TECHNIQUE OF CONSTRUCTION

What coverings should be used for surfaces from which cistern water is collected, to prevent discoloration and bad taste?
Is a unit system of barn design feasible or desirable?
What are the best construction methods for each of the materials that are suitable for barn construction?
Is rammed earth a suitable material for barn construction?
What can be done structurally to reduce fire hazards in barns?
What can be done structurally to reduce wind damage to barns?
What can be done structurally to prevent or reduce damage by rodents?
How can whitewash be prepared to increase its service; also to secure greater adhesion to various surfaces? Can whitewash be sprayed on satisfactorily with farm spraying equipment?
What is the best method of checking or preventing the injurious action of silage on silos?
What are the requirements as to number and location of illuminating units in dairy barns?
Standardization of barn doors and hardware requirements for such doors. (Design of a door that will successfully meet the conditions imposed by the extreme differences in atmospheric conditions that may exist on either side of it.)
Study of barn construction details with a view to economy of labor and materials.
Proper foundations for various farm-storage buildings.

POULTRY HOUSING

Of livestock shelters, the poultry house is next in importance to the dairy barn. While the individual units are smaller and public control has not seemed necessary, the design of poultry houses is an im-

portant national problem. Figure 5 shows that nearly every State is engaged in poultry raising to a considerable extent. This industry is carried on largely under climatic conditions that render housing necessary for effective production. Poultry housing is perhaps standardized to a less degree than any other type. Upward of 150 different designs are now available for distribution by State and Federal agencies. Opinion, and a desire to individuality, have been

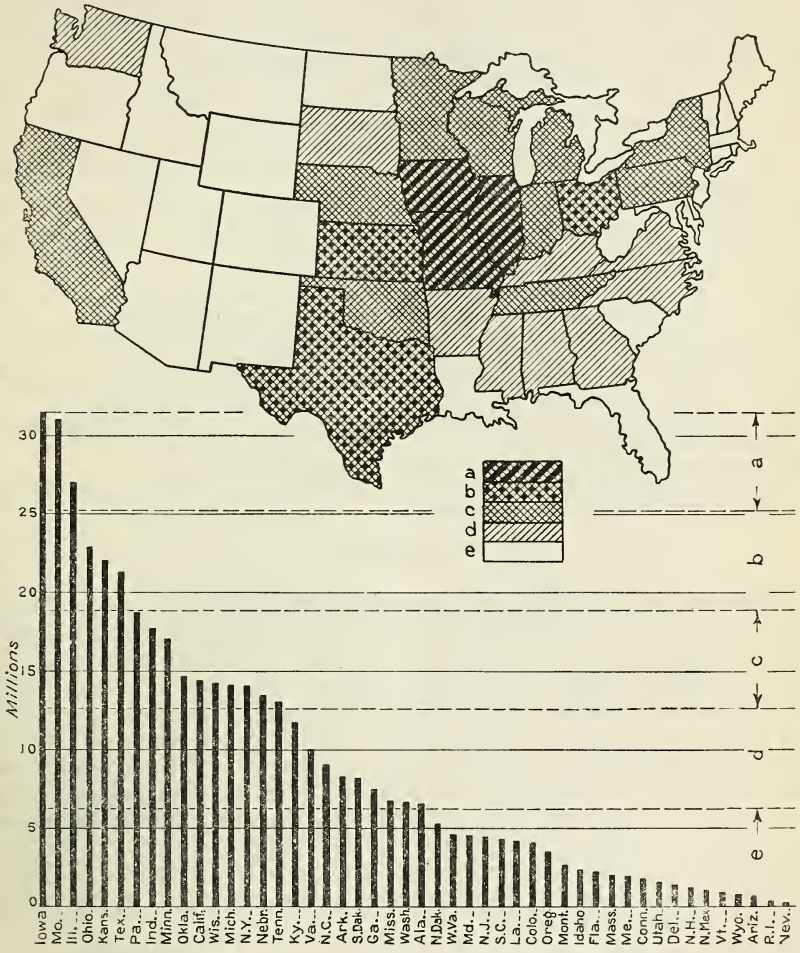

FIGURE 5.—Poultry on farms, by States, 5-year average (1925–1929)

responsible for this variation. Poultry-housing problems are similar in character to those of dairy housing. The great need now is to determine the relation of housing to management, to ascertain whether there would be economic advantage in building houses to provide certain definite environmental conditions, and then to determine just what these conditions are.

It is well known that certain atmospheric conditions cause a drop in egg production. A study of the factors causing variation in pro-

duction, and the building of houses to overcome them, would tend toward stabilizing the market and making egg production more profitable. The fallacy of the belief that impure air in poultry houses is detrimental has been established, but the comfort zone is not definitely known.

A few poultry-housing problems are listed below:

What proportion of the total cost of producing poultry and eggs is chargeable to the use of buildings, and how much influence may the building have upon labor of operation, cost of feed, health and growth of birds, and production of eggs?
How much building overhead is justified in poultry raising?
How will probable changes in management affect construction?
How do environmental factors such as temperature, relative humidity, and rate of air movement affect bird health and production?
What is the normal metabolism of a hen under conditions of production and how far can this be increased without loss of efficiency? (This has a direct bearing upon structural design.)
What protection against heat is required for housing in warm climates?
Does housing practice affect the time of moulting? If so, how can moulting be controlled to fall within the cheap-egg season?
A study of the relation of buildings to sanitation.
What are the building requirements of commercial hatcheries?
What are the building requirements of commercial fattening plants?
How can the environmental factors of temperature, relative humidity, and rate of air movement be controlled effectively and efficiently?
How can labor and materials be best combined in standardized types of poultry houses, due consideration being given to avoiding high depreciation?
What heat-transmission coefficients are necessary for walls and ceilings under various climatic conditions?
How can the heating of brooder houses be improved?
A study of design for maximum uniform lighting and heating during the day from the sun in the winter season.

HOG HOUSING

Hog raising is an industry practiced extensively in a few States and to some extent in all States. It is decidedly regional in character. Figure 6 shows that the principal production area is in the North Central States, coinciding roughly with that of corn. This area experiences rather severe winter weather. The relation of housing to management is, perhaps, more pronounced in the case of hogs than in respect to other animals. The prevalence of the round worm has resulted in a campaign for keeping hogs on fresh ground and has brought a demand for portable hog houses. These, however, present management difficulties. The relation between the critical temperature of the hog and housing should be established. Much remains to be done in standardizing construction. Twelve rather general problems are stated:

What proportion of the total cost of producing pork is chargeable to the use of buildings, and how much influence may the building have upon labor of operation, cost of feed, health of animals, and gains in weight?
How much building overhead is justified in hog raising?
How will probable changes in management affect construction?
How do environmental conditions, such as temperature, relative humidity, rate of air movement, and air purity, affect animal health and production?
What is a hog's critical temperature? Has it any relation to housing or production?
A comparative study of centralized, movable, and combination systems in hog raising.
What are the space requirements in hog raising?

How can the environmental factors of temperature, relative humidity, and rate of air movement be controlled effectively?
How can labor and materials be best combined in standard types of hog-house construction, due consideration being given to avoiding high depreciation?
What heat-transmission coefficients are necessary for walls and ceilings under various climatic conditions?
Hog-house floors and their advantages.
The relation between buildings and sanitation.

STORAGE OF FRUITS AND VEGETABLES

Some of the most acute housing problems are in connection with the storage of fruits and vegetables. Figure 7 shows the production of apples, Figure 8 of white potatoes, and Figure 9 of sweetpotatoes.

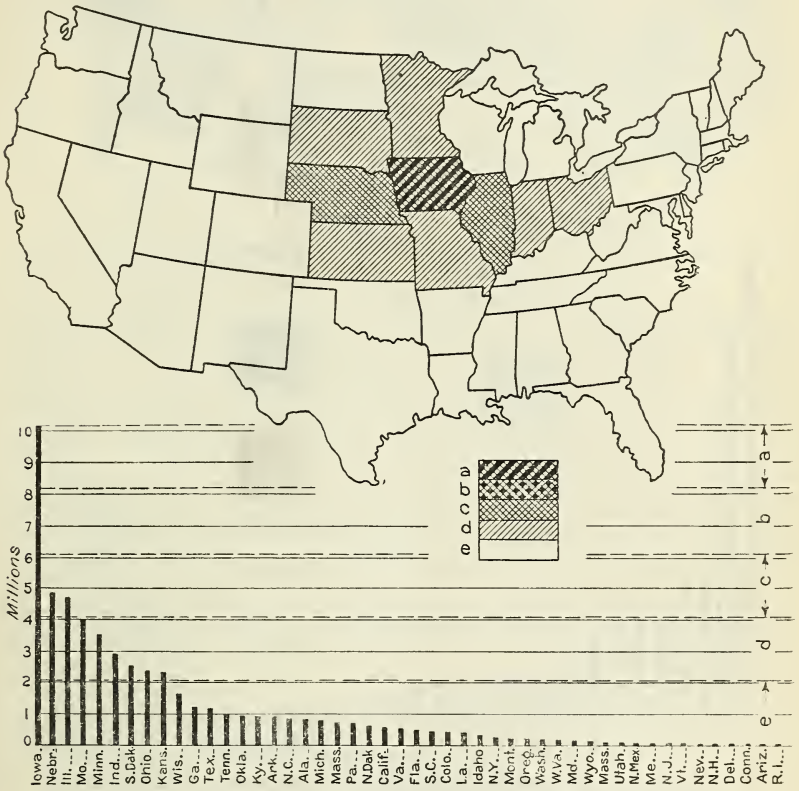

FIGURE 6.—Hogs on farms, by States, 5-year average (1925–1929)

Information on storages is needed in most of the States. The problems of storage for different products vary widely. The production of apples is regional with widely scattered areas. White potatoes generally are produced in the northern States while sweetpotatoes come from the South and Southeast. The optimum storage conditions are not definitely known, but enough research has been done to show that it may not be desirable to store two products in the same room owing to the differing storage requirements. The public demands fresh fruits the year around. To supply this demand better storage methods must be developed, and cut-and-try pro-

cedure is slow and expensive. The agricultural engineer should assist the horticulturist in providing and maintaining technical control of conditions in studies designed to determine how the period of marketability can be extended. It is rather generally felt in some sections that produce held in common storage holds up better after removal from storage than produce that has been in cold stor-

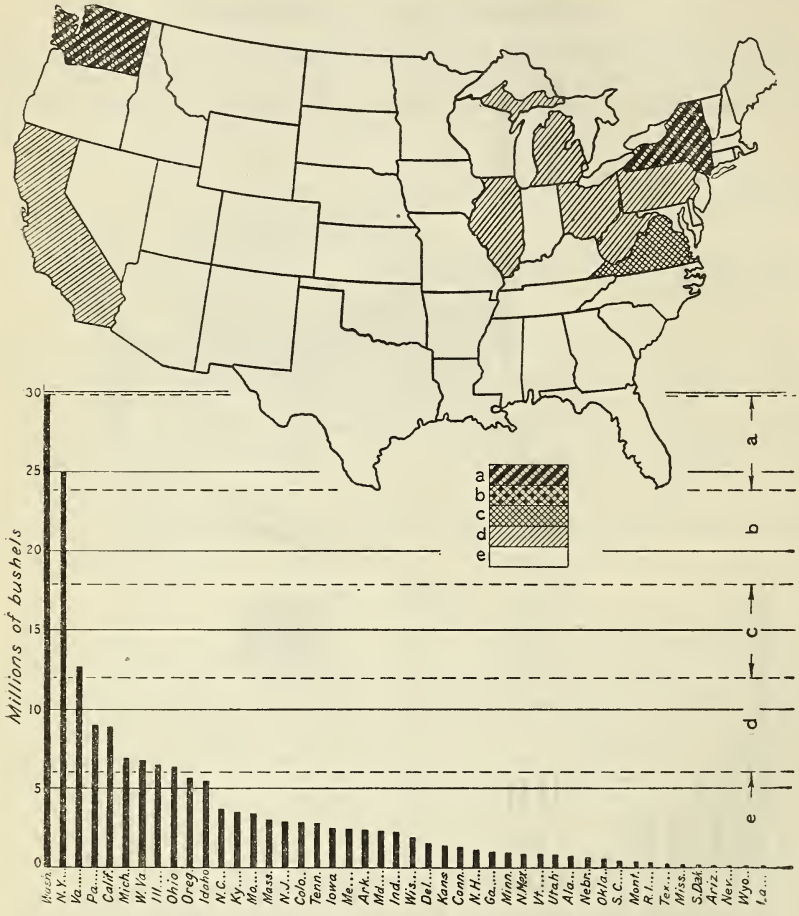

FIGURE 7.—Apple production, by States, 5-year average (1925–1929)

age. However, in many sections early harvesting is necessary to protect the crops from severe frosts, and a warm period of 30 to 60 days often follows and tends to rot the crop under common storage conditions.

The problems in respect to fruits and vegetables are in general similar, but the requirements of particular crops and the variations in climatic conditions necessitate differences in storage practices. The problems relating to apple storage include:

What are the cost factors in apple production?
Is farm storage necessary or advisable? How much influence may it exert upon length of marketing period, and total returns received?
How much building overhead is justified for storage?
What environmental conditions of temperature, relative humidity, and rate of air flow are necessary to preserve apples in a marketable condition?
Where is the climatic and time limit as between common storage and cold storage? (This has a bearing on the design of storages for various climatic conditions.)

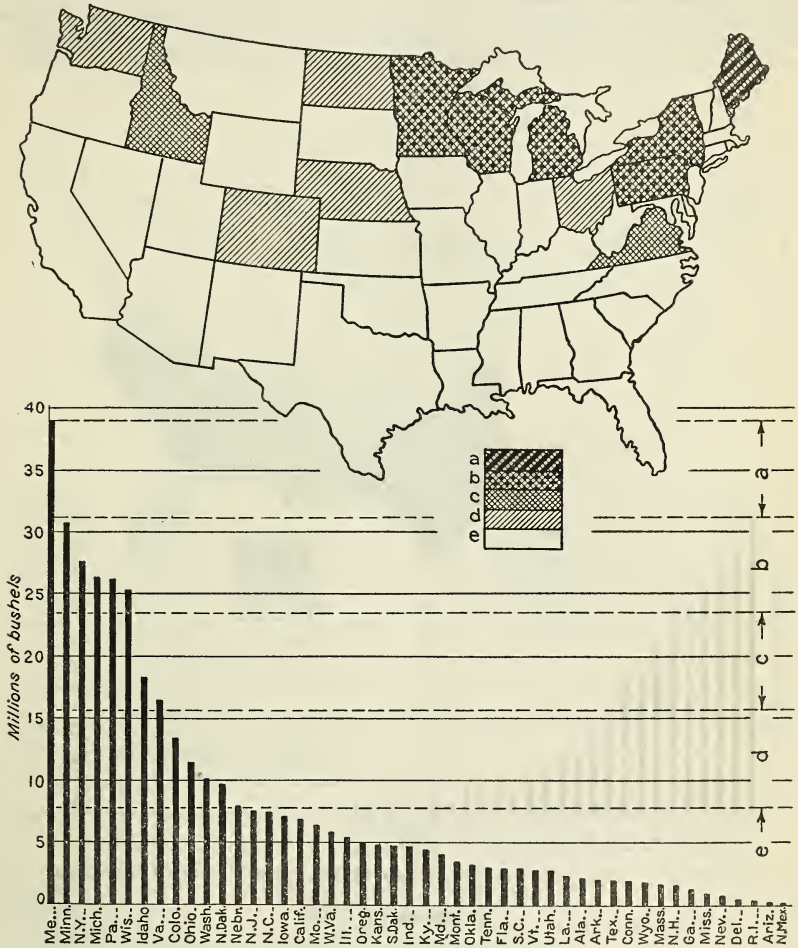

FIGURE 8.—White-potato production, by States, 5-year average (1925–1929)

How can the above requirements best be met in construction?
How can low temperatures best be maintained during early storage?
Can better handling methods be developed to reduce loss?

Some of the problems relating to vegetable and root storage are:

An analysis of cost factors in production, and the relative amount chargeable to storage.
A study of the necessity for storage, and its influence upon marketability and extension of marketing period and total returns?

How much building overhead can be justified for storage?
What environmental conditions of temperature, relative humidity, and rate of air flow are necessary to preserve the produrt in a marketable condition?
Where is the climatic and time limit as between common storage and cold storage?
Studies in space requirements.
Storage methods which will facilitate removal of a part of the product without disturbing the remainder.
Study of means for controlling temperatures for vegetables, during the earlier part of the storage season.
What influence does the ground temperature exert upon underground storages?
An investigation of ground temperatures and an analysis and tabulation of climatological data for different sections as applying to farm buildings.

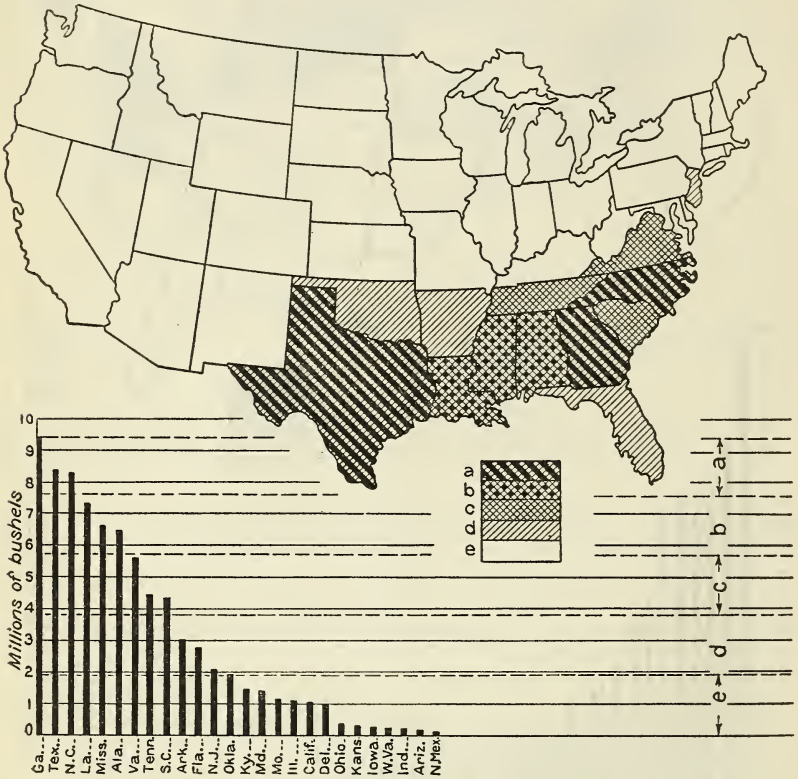

FIGURE 9.—Sweetpotato production, by States, 5-year average (1925–1929)

STORAGE OF CORN

One of the acute problems in the mid-West is the proper storage of corn. (Fig. 10.) In Iowa, which normally is the largest producer, only about 20 per cent leaves the farm. Since the remainder is fed to livestock the problem is not whether to store, but how to store. In approximately one year in five, a short-growing season produces a crop of high moisture content. The drying of seed corn, which must be gathered before damage by frost, has become a very important problem. There is a possibility for useful service in the design of a storage building that will be readily convertible and usable for either ear corn, shelled corn, or small grains. The pre-

valence of the weevil in some sections justifies the development of storages that will facilitate fumigation and still not interfere with adequate curing.

A few specific problems in corn storage are listed below:

What are the various cost factors in corn production? Is storage necessary or advisable? How much influence may it exert upon labor overload at harvest, marketability and feeding value?

How much building overhead is justified for storage?

What type of structure is best in sections where the weevil is prevalent? (There is a demand for structures that can be fumigated, and at the same time permit of proper ventilation.)

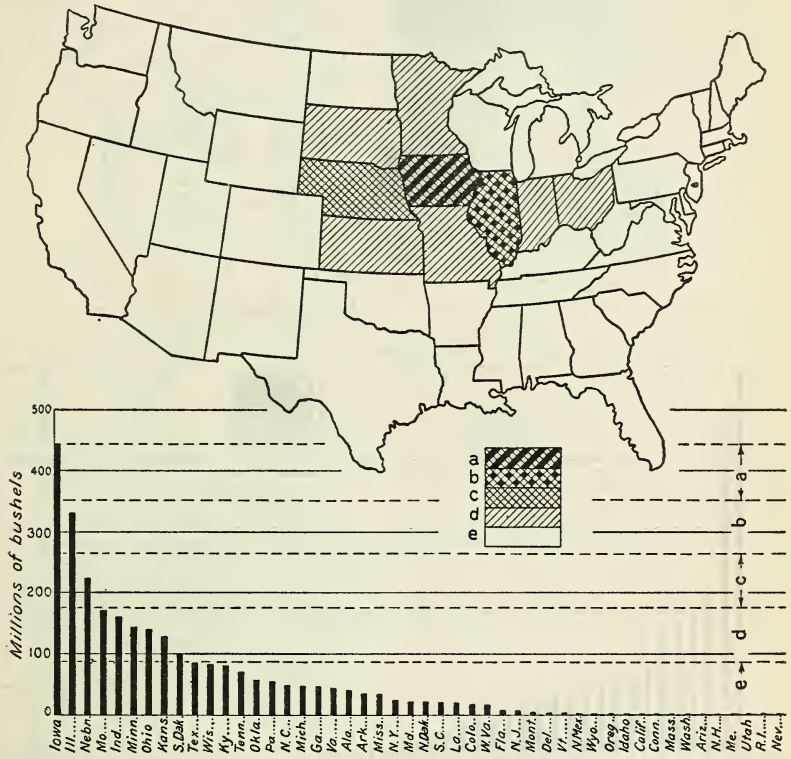

FIGURE 10.—Corn production, by States, 5-year average (1925–1929)

What pressures are exerted upon crib walls and floors by ear corn? By shelled corn?

What are the proper angles for hopper bottoms for ear corn and for shelled corn, to insure complete emptying by gravity?

By what means, involving structures, can corn be dried profitably, and what combinations of air temperature and air flow produce the best results?

What is the maximum moisture content of corn for safe storage?

How can the above requirements best be met in construction?

STORAGE OF WHEAT

The storage of wheat has received much consideration recently. The use of the combine not only has shortened the harvest period and thus taxed transportation facilities, but frequently has brought to storage a grain of relatively high moisture content. The construc-

tion of more farm-storage space has been widely advocated. Studies of this problem are now in progress, notably at the Kansas Agricultural Experiment Station. As shown in Figure 11 there are two distinct wheat-producing regions. The needs of these regions differ somewhat. While the storage of wheat is decidedly a regional matter, the acuteness of its problems has brought it to national attention. Among the problems of wheat storage are:

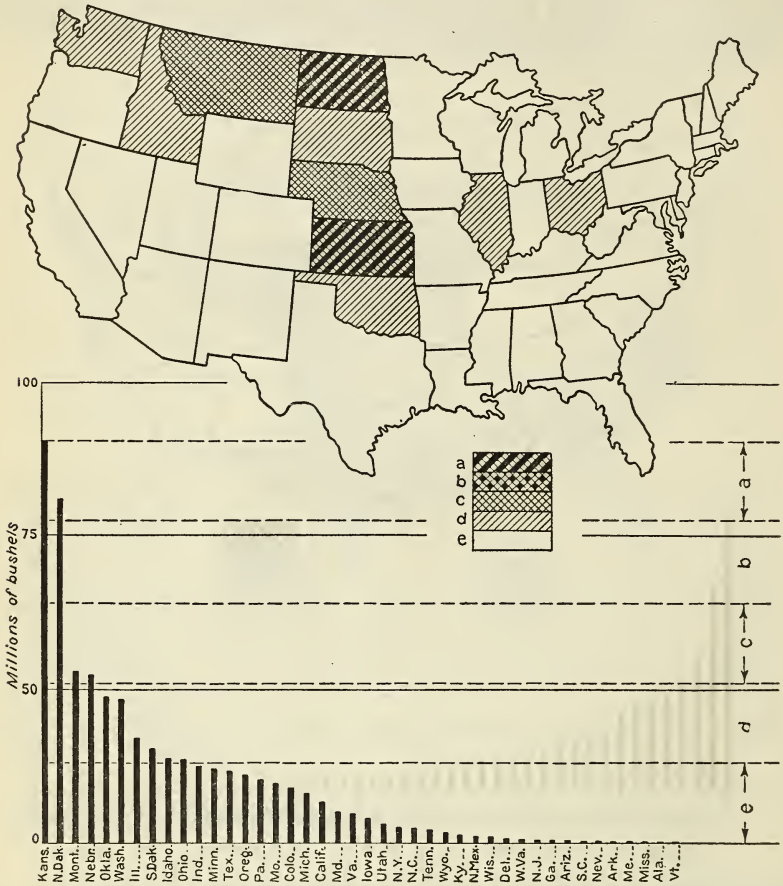

FIGURE 11.—Wheat production, by States, 5-year average (1925–1929)

What are the various cost factors in wheat and small-grain production?
Is storage necessary or advisable? How much influence may it exert upon labor overload at harvest, and upon marketability and price?
How much building overhead is justified for storage?
What pressures are exerted upon the walls and floors of bins by wheat and other small grains?
What are the proper angles for hopper bottoms for grains to insure complete emptying by gravity?
What conditions of temperature, relative humidity, and air flow are most effective in drying wheat of high moisture content?
How much moisture can the grain contain and still be stored safely?
How can the above requirements best be met in construction?
A study of the requirements of grain-storage buildings with reference to the installation of grain drying, grinding, and handling equipment.

STORAGE OF TOBACCO

Although the production area of tobacco covers nearly all the eastern half of the United States, very few States are large producers, as shown in Figure 12. Building construction and curing methods differ widely. In many cases the curing is done by rule-of-thumb methods, and the product frequently is rendered valueless by careless handling. Tobacco as a cash crop is quite important to certain sections, and the better methods of storing it are necessary

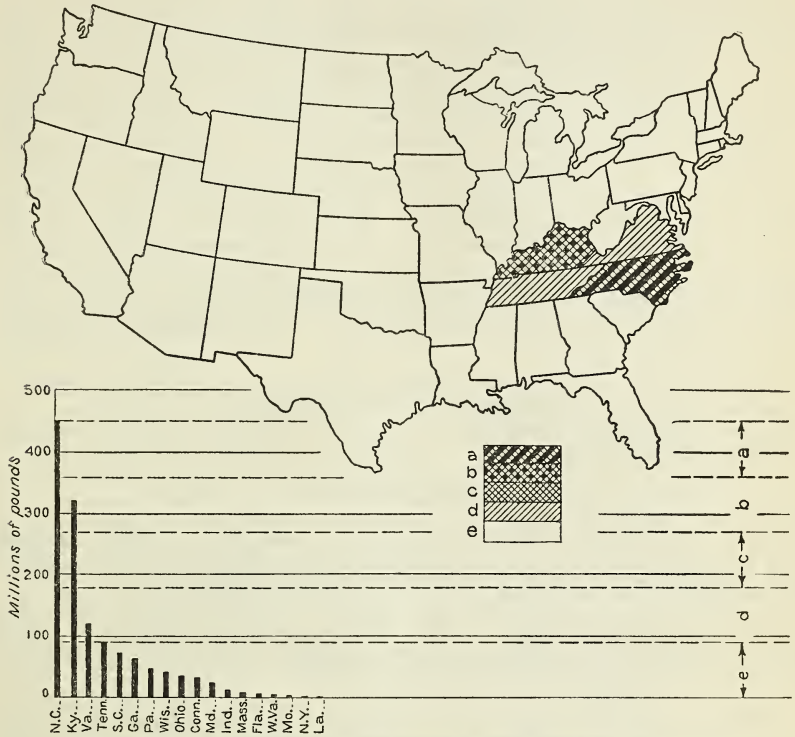

FIGURE 12.—Tobacco production, by States, 5-year average (1925–1929)

for satisfactory results. Better construction methods are necessary for barns naturally ventilated. From section where heat cures are used, there comes a definite demand for information as to the temperatures and the rates of air flow that should be maintained. Careful consideration should be given to control methods. The problems of tobacco storage include:

Can tobacco be cured economically by mechanical ventilation?
Is mechanical curing feasible in farm storages, or is it purely a community or cooperative undertaking?
How would mechanical ventilation affect market and warehouse?
How much building charge is justified for farm storages?
What influence would mechanical curing have upon the flavor of the leaf?

What combinations of temperature, relative humidity, and rate of air flow are required for the best results?
How can the proper control of environmental factors (temperature, relative humidity, and air flow) be established and maintained?
How can the present design of tobacco barns be improved to assure longer life and better efficiency in handling?

STORAGE OF MACHINERY

There has been much discussion as to the necessity or advisability of storing machinery. Since one of the larger cost items in the use of machinery is obsolescence (*10*) the value of housing has been questioned. Nearly all States have large investments in farm machinery. Undoubtedly, corrosion and general deterioration are more rapid in some sections than in others, because of climatic conditions, so a practice that is justifiable in one locality may not be advisable in another. One operator of a large farm in a dry area said that the effect on his own morale was sufficient to justify housing his machinery. In any event the question of whether or not to house is worthy of careful consideration. Where machine sheds are employed, there is a distinct need for a study of construction methods. Several large openings usually must be provided, with little opportunity for bracing. The extent to which a machine shed is used may be determined by its accessibility. Two problems of housing machinery are:

Is the housing of implements advisable? (This is in some measure a regional question, owing to prevailing differences in atmospheric conditions).
How can buildings be adequately constructed without interfering with the moving of machinery?

FARM FENCES

Little consideration has been given to the farm fence. Lyman (*22*) has shown the need of a study of this subject and has analyzed the problems for the Farm Fence Institute as follows:

Analysis of existing fences to learn extent, condition, replacement needed, economic length of life compared with actual period of use, extent of nonmetal fences, and investigation of fence markets by class.

Economics of fencing:
- Income producing value of fence in different farming systems.
- Relation of fence to profitable livestock production.
- Relation of fence to maintenance of soil fertility.
- Relation of fence to labor economy.
- Relation of fence to economy of equipment operation.
- Relation of fence to farm valuation.
- Relation of fence to tenant problem—
  - Profit to tenant.
  - Profit to landlord—
    - Ability to secure good tenants.
    - Increased income.
- Relation of fence to increased farm production per unit of area—
  - Crop rotation.
  - Soil fertility.
  - Efficient and economical animal production.
- Relation of fence to sales value of a farm as affects—
  - Mortgage bankers.
  - Local banks.
  - Insurance companies.
  - Individuals.
- Economic length of life of fences.
- Value and uses of temporary and permanent fences.

Mechanics of fencing:
Suitable types for various uses.
Construction.
Maintenance.
Comparative study of posts by materials and uses.

HEATING, VENTILATION, AND INSULATION

Temperature control in farm buildings is now recognized as of utmost importance. In many cases proper insulation will conserve the available natural heat and render artificial heating unnecessary. Careful studies of heating and ventilation problems are justified, with the object of developing new methods and materials for these purposes. Such studies should cover the following problems:

The use of sawdust for insulation; treatment to make it objectionable to mice and insects, and to reduce moisture absorption. (The disposition of sawdust is a real problem in a number of States. It is a fire hazard and is not a good fertilizer.)
Does insulation affect animal production, and if so, how?
What are the insulation requirements for animal shelters in the various climatic zones?
Is artificial heating of animal shelters desirable or necessary? If so, how can it best be accomplished?
What are the relations between heat-transmission coefficients as determined for laboratory-test units of small area and for the large areas presented in completed buildings?
How can the original cost and maintenance costs of heating systems for greenhouses be reduced?

WIND AND FIRE LOSSES

The losses due to fire and wind are truly economic losses. While the individual may be partly protected by insurance, the loss must be paid ultimately by the agricultural industry. The tremendous losses of life as well as of property from farm fires is the more inexcusable because they are largely preventable.

Studies should include investigations as to the reasons for these losses and as to improved construction methods for reducing future losses.

Is the present lightning-rod system adequate, or should lightning towers be used?
How can farm smokehouses be constructed to avoid fire hazard?
What is the relation between farm water supply and fire protection?
Which is best economic practice—to separate buildings to reduce fire hazard, to build of slow burning or fire-proof construction, to provide adequate water supply for fighting farm fires, or to provide some combination of the foregoing?
What can be done structurally to eliminate fire hazards in farm buildings (particularly hay storages)?
Should metal barn equipment be grounded to prevent damage by lightning? If so, how?
Requirements for fireproof engine houses and pump houses for rice farms.
A study of farm-building framing with reference to resistance to wind pressure.
A study of pressures (amount and distribution) exerted on various farm buildings by wind (including side and end walls and roofs).
What are the weak points in construction of farm buildings with reference to wind resistance, and how can existing buildings be strengthened economically?
A study of anchorage for farm buildings to resist wind pressure.

USE OF MATERIALS

New materials are constantly being developed. The suitability of these for farm uses should be studied. Some undoubtedly are of great value and others serviceable, if properly used. Even some of

the better-known materials are not being used to best advantage. These studies offer unusual opportunities for cooperative research between the industries and the State experiment stations. The following are but a few of the many problems that should receive attention:

A comparative study of circular and square concrete water tanks. (Circular tanks are more desirable structurally but are more difficult to build unless special forms are available.)
A study of the bearing values of bolts and nails and the development of better methods of fastening timber construction.
A study of barn failures caused by improper bracing or lack of bracing, and of methods of straightening and bracing buildings which have become deformed.
Utilization of odd and short lengths of lumber.
Standard construction details for all classes of building materials as used in farm buildings.
Utilization of new materials.
To what extent can rammed earth be utilized as a farm-building material?
Use of local materials in farm-building construction.

MISCELLANEOUS PROBLEMS

In addition to the foregoing rather arbitrarily classified problems there are a number, more general in character, that may apply to specific buildings or to certain kinds of buildings. Some are rather simple problems that can be handled at little expense, while others are more comprehensive.

To what extent is faulty chimney construction responsible for residence fires, and how can this loss be avoided?
Is the Flagg system of residence construction practical for farm homes and what, if any, modifications are desirable?
Does the suburban home satisfy rural conditions?
To what extent can farm dwellings be standardized?
Can a dry, comfortable floor of concrete be built directly on the ground or should there be an air space under it? (Placing the floor on the ground would eliminate objections which are common when a raised wood-floor system is used in warm sections, in tenants' and laborers' cottages.)
Farm kitchen studies, including efficient planning and equipment.
A study of residence requirements: Room requirements as to space, light, ventilation, temperature; construction requirements as to joist sizes and spacing, wind hazards, wind bracing, fire hazards; also plumbing, heating, and electrical refrigeration.
A study of the relationship between the initial cost and permanence in farm-building construction.
A survey of farm-building construction and farm-building needs.
How does the arrangement of buildings in a farmstead affect the operating labor charges?
An analytical study of barn-roof framing. What is the most desirable design, taking into consideration economy of materials and labor, as well as conformation to structural requirements?
Do farm buildings depreciate more from obsolescence than from deterioration? (This question is of especial interest as it affects the substantiality required for farm construction.)
Is the unit system in farm-building design feasible or desirable?
To what extent can farm-building equipment be standardized?
What can be done structurally to reduce or prevent damage by rodents?
What is a cheap and durable paint for barns and certain other farm structures? (White lead is affected by fumes from manure.)
How can structures be damp-proofed economically after they are built? (This is an important problem in below-ground structures such as cisterns, cellars, and storage caves.)

How can creosote and soot best be cleaned from chimneys and heating equipment?
Durability studies: Carefully conducted tests are needed to determine the life and maintenance cost of roofing, wall coverings (including stucco), floors, hollow building tile, glass substitutes, paint and other preservatives and stucco bases.
A study of destructive agencies met in farm-building construction (e. g., insects, fire, wind, moisture, temperature, etc.) and methods of reducing losses caused thereby.
A study of rural building codes.
A study of foundations for all farm buildings.
The construction of temporary buildings from cheap materials such as earth and straw.
What are the housing requirements of tractors, trucks, and automobiles?
The design of fruit packing, shipping, and curing houses.
The design of feed-yard equipment for sheep, poultry, hogs, and cattle.
A study of glass substitutes as to life, heat transfer, transmission of ultra-violet rays, etc.
A study of the flow of air through wire mesh and fabric. (This is of value in design of ventilation systems.)
A study of rural sanitary equipment.
What is the most practical roofing for farm buildings? What specifications are desirable?
What is a suitable dressing to prolong the life of felt roof coverings?
What roof coverings should be used for surfaces from which cistern water is collected, to prevent discoloration and bad taste?

It will be seen at once that few of the foregoing are strictly State problems. Whether a problem relates to economics, management, service requirements, or the technique of construction in relation to a particular agricultural enterprise, it is of considerable importance to several States and of some importance to many. Including only the two groups of States of highest production in each enterprise (groups *a* and *b*, figs. 4 to 12), which in most cases represent a relatively large production, it will be observed that several States are involved. In dairy production these groups include Wisconsin, Minnesota, New York, and Iowa; in poultry production, Iowa, Missouri, Illinois, Kansas, Ohio, and Texas are included. Besides Minnesota, Maine, Michigan, New York, Pennsylvania, and Wisconsin in the first two groups in white-potato production, Virginia and Idaho are large producers. The condition is similar in the other lines. Even in hog raising and tobacco production, which are quite localized, several States are appreciably involved. Few, if any, of the problems are important in all States.

This situation offers possibilities for organization and united effort to secure a simplified practice. National marketing of materials justifies national standards of construction. The present recommendations frequently are confusing. If four dairy farmers situated in practically adjacent territory, but one each in Wisconsin, Minnesota, Illinois, and Iowa, were to request information and building plans from their respective State colleges, the replies would show considerable differences although as a matter of fact the requirements are practically identical. Should a fifth farmer in that section write to the United States Department of Agriculture, he might get a still different answer. This difference in handling can show only one thing, that much of the present data are in the realm of opinion. The situation is of course not peculiar to the States mentioned; it may be even more pronounced in other localities.

RESPONSIBILITY FOR LEADERSHIP

If several States are interested in common problems, proper solution depends upon their ability to correlate their efforts. This may or may not mean cooperative effort. It does require, however, a close relationship among the States, a dividing of responsibility which will enable one State to carry certain projects and to use the results obtained by other States on other problems. Such relationship will not come spontaneously, it must result from definite initiative. It has been suggested that representatives from the States interested in a given type of housing form a committee to analyze the problems relating to that type, assign research problems to the various experiment stations, and eventually set up standards for design and construction. However, the workers in the various stations now have heavy schedules which discourage their carrying extra-curricular activities. Correspondence is generally ineffective and most workers have difficulty in securing authorization for official travel beyond their own State boundaries. Moreover, the question arises as to which State could or should assume the leadership? Such a committee for considering potato storages would need to be entirely duplicated for obtaining correlation in the study of poultry housing, or of hog housing, which affect quite different groups of States.

Centralized leadership is essential for effective effort. The individual States are unable to assume the initiative. In making this survey, the writer endeavored to interpret the attitude of the various station directors and others as to the relationship which should exist between the United States Department of Agriculture and their organizations. Without exception the directors indicated that Federal responsibility is one of leadership and correlation. The Federal organization is expected to carry national leadership and must command respect in that capacity. It should handle problems that are interstate and national in character and therefore should not constitute a competing research agency with the States. The Federal Government should coordinate but the responsibility for performance should rest largely with the individual States.

Independent work usually is conducted with insufficient vision and is lacking in articulation with the work of others. Within an experiment station, interdepartmental cooperation can be increased through outside interest and leadership. Cooperative projects between individual States and the Federal Bureau of Agricultural Engineering offer the most effective means of getting results from a given budget. One college dean emphatically stated that Government contact had materially increased production in one line at his institution, even though not accompanied by Federal personnel or funds. One station director said that in a certain line of effort, coordination was virtually being effected by a representative of industry who had no official connection with either State or Federal Government. This, however, is not to be expected generally, and the United States Department of Agriculture is the organization preeminently situated to initiate a program of coordinated research.

As already pointed out, a number of State experiment stations have committed themselves to some studies relating to farm structures. All stations visited indicated a desire to participate in a national program. This does not imply any great increase of effort

at once. Practically all stations find themselves with limited funds, well established research in other lines that can not well be dropped, and many emergency problems. Coordination appeals to them as it seems to offer a program which can be realized. The assurance that other States will participate will be a stimulating influence.

The relations between the United States Department of Agriculture and the several State stations is a subject worthy of the closest consideration. Their interests or fields of activity are not conflicting and a spirit of cooperation is essential to satisfactory results. Ultimately the support of the Federal organization comes from the several States. There is a growing feeling upon the part of the States that this money should be spent largely with and through the States. Many building problems can be studied only in the environment in which the problems exist. The Federal organization may need laboratories which are already available in one or more of the States. By correlating the national viewpoint of the Federal worker with the local viewpoint of the State workers, most problems can be handled with greatest effectiveness.

The attitude of the individual worker can not be ignored in formulating any research program. After all personality is the most important factor in research and may either make or break an otherwise well developed and well organized program. Several station directors have stated that their problem is to find a well-qualified man. Once they have him, they place all possible resources at his disposal.

The welfare of industry is often closely allied to that of public institutions. Industry as a tax-paying agency is entitled to governmental assistance. Satisfactory farm construction presupposes correct usages of materials. The majority of the materials groups now have trade associations which represent nearly all the production in their various lines. The correct usage of materials is as vital to them as to the user. It would be a short-sighted policy that would recommend a material for uses to which it is not suited. Research is needed to determine what materials are in fact suitable for particular purposes, and in this there should be close cooperation between the Federal Government and the various trade associations representing the manufacturers of building materials and equipment. A number of industries have recognized the value of cooperation with the State experiment stations in seeking solutions of their problems. This makes possible savings in laboratory construction and equipment; it also should assure impartial conduct of the investigations and more general acceptance of the results. That the industries are using college facilities is shown by Gray (*19*) who, in a discussion of the relation of colleges of agriculture to industrial workers, says:

> * * * I do know that we must work with a large number running, perhaps, into the hundreds as far as our own single State [Arkansas] is concerned. * * *
>
> We are going to keep in mind that the advantages which come to our organization and through it to the people of Arkansas while working with commercial educators are about as follows:
>
> 1.—Commercial organizations sometimes establish scholarships and fellowships and, as a result of such activities, studies of certain research problems are advancing more rapidly than otherwise, and at the same time a few young men and women are trained for the scientific world who otherwise might never have had opportunities for advanced work.

In discussing fellowships and their relation to research, Russell (*26*) says:

> In this connection I should like to mention our (Wisconsin) results with the system of industrial fellowships that has been developed in the last decade. I believe it offers an excellent opportunity for research work to be broadened under conditions that safeguard the independence of the college and yet are supported from other sources than public taxation.
>
> From time to time we are offered funds by various interests (agricultural organizations, general business associations, commercial concerns, and individuals) for the purpose of enlarging the scope and activity of definite research projects. These applications are investigated on their individual merits and where it is determined that the problem to be studied can be wisely undertaken, memorandum agreements are entered into between the board of regents of the university and the cooperating organizations or individual.
>
> The station in perfecting this arrangement retains full autonomy of the work with respect to selection of incumbent to fellowship, his salary and assignment, and the right to publish the results in any manner it may see fit, keeping foremost the idea that the public interests are first to be subserved.
>
> It is interesting to note that a large part of these funds are being used for research of a general fundamental nature. By far the larger part of the projects under investigation would be wholly within the purview of support from State funds. This expression of confidence on the part of business shows the attitude of such groups toward the belief that science can serve the advancement of mankind.
>
> We have in operation now [1929] over 30 such fellowships that are supported to the extent of over $75,000. Through this medium we have been able to expand greatly our research program, and to no small extent this new avenue of support has been the means of development of our graduate work in agriculture. Not infrequently incumbents of these fellowships are taken over by the cooperating organizations in a permanent way.

Industrial fellowships offer possibilities in overcoming some of the difficulties previously mentioned for the present lack of research effort, by increasing interest and developing a trained personnel. Cooperative relationships will result in a better understanding between the industries and public research workers and will provide the manufacturers with a sound basis upon which to build their educational programs. The success of these fellowships depends very largely upon three factors: The importance and timeliness of the problem, the ability of the incumbent to accomplish results, and the quality of supervision given after the project is started. A specific and obvious need should provide the foundation of all such effort. Before an agreement is entered into, both contracting parties should be satisfied that the proposed organization of the project shows a reasonable probability of producing results which will be mutually beneficial.

The advisory council at its first meeting had expressed the need for a clearer conception of the farm-structures situation. This was recognized as an undertaking which could not be accomplished in a single year, not alone for lack of time but also because a changing situation requires constant contact. That some progress has been made since the council meeting is indicated in the recommendations for a national program which follow. Personal contact and sympathetic understanding are necessary for the successful conduct of a cooperative undertaking. The head of farm structures work at Washington must be in the field a considerable portion of the time if he is to obtain first-hand information regarding his field of work.

He must have a national consciousness and maintain a sympathetic acquaintance with the individual workers. Nothing can take the place of frequent field experience. Moreover, the individual workers in the States need and deserve this Federal contact and cooperation. Several have definitely expressed a desire for such a relationship. A Federal representative, familiar with the environment of the workers, can materially assist in increasing the scope of the work carried on and in enhancing its quality.

A NATIONAL PROGRAM

In discussing the reasons for the present lack of research effort, it was suggested that service demands have usurped so much of the agricultural engineer's time that little has been left for fundamental study. The multiplicity of problems has doubtless added to the confusion. The time has come, however, for a careful analysis of the various housing problems and for the formulation of a logical approach and definite policy. It has been shown that housing problems are regional, seldom local or national; efficiency in farm-structures research necessitates national leadership; close cooperation should be maintained between State and Federal research organizations; and the United States Department of Agriculture is preeminently in a position to initiate and carry on a coordinated program. Obviously, the responsibilities involved must be definitely placed upon one person. The advisory council at its second session in Chicago, on May 23, 1930, reported to the Secretary of Agriculture as follows:

Whereas you have invited a group of organizations and industries relating to agriculture to designate representatives to be members of an advisory council in connection with a preliminary study of the farm-structures research situation, and

Whereas we believe that leadership in such an effort should most properly be established at the United States Department of Agriculture, Division of Agricultural Engineering.

Be it resolved that it is the unanimous sense of this group representing the various interests invited by you to participate, that the work conducted this year should be continued and enlarged and carried on as an activity of the United States Department of Agriculture, Division of Agricultural Engineering.

Your advisory council recommends the following general course of procedure:

That an agricultural engineer of adequate training be designated by the Division of Agricultural Engineering, United States Department of Agriculture, to organize and direct the program and whose duties and responsibilities in general shall be—

First. To develop a program of coordinated research of farm structures having in mind projects of pressing national and regional significance.

Second. To maintain intimate contact with farm-structures workers at the various State colleges and experiment stations for the purpose of stimulating their interest in proper projects and of coordinating their efforts with others working along the same line as a means of avoiding unnecessary duplication of effort.

Third. To foster a spirit of active cooperation between national and State research institutions in the structures field.

Fourth. To maintain a close relation with industrial, technical and educational agencies through direct contact with a permanent advisory council representing these interests in order properly to interpret the specific needs of industry and agriculture to the research agencies.

It is the conclusion of your council that only through this well-defined program can proper solutions of all the vital problems in this field be reached.

In these recommendations, first consideration is placed upon the necessity for definite leadership. One man who devotes his entire time to stimulating, encouraging, and assisting State workers will advance the program much more rapidly than is possible by working independently on research problems. He would be expected, then, (a) to study constantly the national situation; (b) to plan and supervise cooperative research, (c) to stimulate and correlate the efforts of State workers. Contacts should be made with land-grant colleges and universities, State departments of agriculture, commercial organizations, and trade associations. These are not all potentially equal as research agencies, and contact should be maintained accordingly.

The second recommendation of the advisory council emphasized cooperative effort. A systematic attack is desirable in carrying out a national program. Each building should be taken in turn, the economic relationships established, the service requirements determined, and a satisfactory technique developed. One or two housing types national in importance should be selected for first consideration. Local interests may, and probably will, prevent a strictly logical program, so that other more-or-less unrelated projects may have to be carried on simultaneously. The general procedure should be as follows:

1. Select the types of housing for first consideration.
2. Make a complete analysis and list the problems.
3. Invoice present knowledge and check against the list.
4. Invoice research facilities and attempt to organize research on unsolved phases at the institutions that give promise of substantial results.
5. Instigate collateral research as seems advisable locally.
6. Continue the study of conditions in the various States. An outsider can not hope to accomplish much on the first contact, nor all on the second. It would seem presumptuous for him to make very definite suggestions as to the relative importance of certain activities and the best methods of approach, without first making a study of the State, its housing problems, and their relation to those of other States.
7. Organize cooperative effort as rapidly as resources are available.

The farm dwelling is one of the most important of the farm structures. Its influence upon the morale of the farmer and his family can scarcely be overestimated. The director recommends that as soon as facilities permit, the Federal Bureau of Agricultural Engineering in cooperation with a number of State stations, make a study of the remodeling of farm dwellings and carry through at least one project in each of several States. It is assumed that the cooperation of the Bureau of Home Economics and specialists of other organizations may be obtained as necessary. If this is done and the results are compiled and reported, problems of remodeling will be materially simplified; and from the standpoint of the State college, remodeling is much more important than new construction.

The dairy barn ranks next to the farm dwelling in importance to the Nation, among farm buildings. Several States now are giving attention to dairy housing problems or are considering doing so. The development of a national program should commence with the

present situation. The research projects suggested in following paragraphs depart somewhat from the order given in the analysis, but are based upon interpreted interest and work already started. The following States apparently offer possibilities for immediate effort in research relating to dairy housing: California, Iowa, Kansas, Michigan, Minnesota, Mississippi, Nebraska, New Jersey, New York, Ohio, Virginia, and Wisconsin.

California has installed recently an elaborate respiration chamber large enough for dairy cows. Basic studies on individual cows under production can be accomplished there. Information on environmental factors, so badly needed throughout the country, can perhaps be studied better through the use of equipment already installed there than at any other place.

Iowa has made some studies of stall sizes, flooring materials, and the performance of both natural draft and mechanically operated ventilation systems. The first-mentioned should be checked by studies made elsewhere; the others may well be continued at the Iowa station.

Kansas has shown interest in comparative performance under the conventional system of management and under the system of milking barn and loafing shed. The latter type of management is rapidly gaining favor, especially in the milder climates. Studies should include comparison of labor costs, building charges, feed consumption, and quality and quantity of production. Kansas also has available one of the few wind tunnels in the States. Many factors involved in the designing of barns to meet wind loads are not known; in fact, recent studies of the behavior of buildings in wind storms indicate that the design data at present available are far from correct. If feasible, this wind tunnel should be employed for obtaining basic data on wind pressures on farm buildings.

Michigan is now making observations on the behavior of a mechanically-operated ventilation system.

Minnesota has conducted rather extensive studies relating to the lengths of chore routes and efficiency of management. These studies should be continued with a view to determining the most effective arrangement of farmstead and barn.

Nebraska has also shown interest in the investigation of management methods. Studies might well be conducted there in case cooperation should not develop at the Kansas institution.

New Jersey has, in the Walker-Gordon laboratory at Plainsboro, a layout which offers exceptional opportunity for the study of environmental factors, heat production, etc., in large units under full production. There at one plant are 32 barns, each of 50 cows capacity and almost identical in construction. The plant is now being operated in many respects as a research laboratory and already has close working connection with Rutgers University only a few miles away. Some housing studies have been made there. Since the climate there is milder than in some other sections, it might be advisable to make similar studies under more severe conditions.

New York has made extensive observations on the flow of air in barns and has designed natural-draft ventilation systems based upon the findings. The radical nature of the information obtained has revolutionized the conception of air flow and barn ventilation. New York has a definite responsibility to the other States in carrying

this work forward to conclusion and adequately reporting it. New York is also making observations on the performance of a mechanically-operated ventilation system. Other studies now being carried on relate to electric refrigeration and milk-cooling tanks.

Wisconsin is not now reporting active research relating to dairy housing, although the State is the largest producer of dairy products. Severe climatic conditions necessitate more careful housing there than in many other sections. Studies have been made of natural draft and mechanical ventilation, comparative costs of single and 2-story barns, glass areas required, and the justifiable investment in barns. Glass areas and their relation to sanitation, and the standardization of window sizes, constitute an important problem at the present time.

Virginia has comparatively a mild climate. Dairying is increasing rapidly and rigid control ordinances are in effect. Considerable differences exist in the ordinances in effect at the large milk-consuming centers. Most of the ordinances are based on personal opinion and not on research facts. They have created a demand for milk refrigeration. Studies of electric refrigeration and general milk cooling are now under way. Studies at the Virginia station might well include the pertinency of the various requirements of present regulations concerning production and handling of milk. Injustices result from requirements which are irrelevant. The United States Public Health Service emphasizes the need for such studies.

Upon the basis of the conditions stated in the foregoing paragraphs, the following list of projects is recommended as a nucleus for a national program of coordinated research in farm structures.

A TENTATIVE PROGRAM OF COORDINATED RESEARCH IN DAIRY-HOUSING PROBLEMS

CALIFORNIA

What is the critical temperature of the dairy cow under normal conditions of production? What is the comfort zone?

What is the normal metabolism of a dairy cow in production, and how much can this be increased without loss of efficiency?

What is the best method of temperature control for barns in the warmer climates?

IOWA

A study of mechanical ventilation systems for dairy barns. (In progress.)

A study of barn construction with reference to wind and fire resistance. (In progress.)

How can heat of outgoing air (including heat of vaporization and fusion in water vapor) be used to warm incoming air?

KANSAS

For what magnitude and distribution of wind loads should barn-roof trusses be designed? (In progress.)

A study of dairy housing methods—the conventional dairy barn and the milking barn with loafing shed. (Economy of labor, comparative building charge, feed consumption, quality and quantity of product.)

MICHIGAN

What are the relative merits of gravity and mechanical ventilation for dairy barns? (In progress.)

What temperature of drinking water will stimulate greatest consumption?

MINNESOTA

How does the arrangement of buildings in a dairy farmstead affect the operating costs? (In progress.)
What proportion of the total cost of producing milk is chargeable to the use of the building, and how much influence may the building have upon labor charge, cost of feed, health and productive life of stock, and quality and quantity of product?

NEBRASKA

A study of dairy-barn management and equipment most suited to economical operation.

NEW JERSEY. (COOPERATION WITH WALKER-GORDON LABORATORY)

A study of managerial factors that would influence barn design. Should the cows be kept in their stanchions overnight? What is the range of temperatures in which cows may be allowed outside the stable? Is appetite stimulated by exercise? How much exercise is needed?
A study of heat losses from barns, heat production of cows and methods of temperature regulation.

NEW YORK

Studies relating to the flow of air in barns. (In progress.)
Studies relating to the best locations for intake and outtake flues, and their influence upon temperature control and moisture removal. (In progress.)
What heat transmission coefficients are necessary for walls of dairy barns in zones 1 and 2?
What constitutes a draft?
A study of mechanical ventilation systems. (In progress.)
Milk-house design. (In progress.)

OHIO

What materials are most resistant to rust when in proximity to dairy-barn wastes? (Stall partitions rust out quickly where they enter the concrete floor.)
What are the requirements as to number and location of illuminating units in dairy barns?

WISCONSIN

How much building overhead is justified on a dairy farm?
Do barns depreciate more from obsolescence than from deterioration?
How will probable changes in management (chopping and drying of hay) affect barn design?
Time studies in milking?
For how many cows can one man care?
Mechanical handling of milk, manure, and feed.
How many pounds of feed are required to produce a quart of milk?
A study of stanchions. Can present methods of stanchioning cows be changed so as to reduce labor and to house more animals in a given barn?
A study of desirable glass areas in dairy barns.

VIRGINIA

Mechanical refrigeration for small dairies. The economic design of farm dairy plants with special reference to the influence of buildings on other production factors. (In progress.)
Flow of air through fabric. (A study of the effectiveness of ventilating flues covered with various types of fabric.)

All of these projects should receive the support of the advisory council and the United States Department of Agriculture. Each State should feel its responsibility in a national program. Some stations may be able to carry on without financial assistance, but each situation should be considered on its merits and, where necessary, State resources should be supplemented with Federal funds or personnel, or both.

The foregoing recommendations are made upon the basis of immediate procedure and the utilization of interests and facilities as they now seem to exist. They should be considered as units in a complete analysis or, as one has said, "individual tiles in a great mosaic." A national need justifies an attempt at national coordination of effort.

There is recommended a further analysis of the dairy-housing problem, a careful study of such phases as may already have been determined experimentally, and the expansion of a research program as rapidly as present projects are completed or new facilities developed. New undertakings should follow the order given in the analysis, as far as may seem desirable considering special interests affected or facilities available. Careful attention should be given to the training of new workers. A common fault is to attempt projects that are too comprehensive considering the personnel available. Some of those listed herein were chosen purposely as being fairly simple. Once a project is started, ramifications and complications often appear and a seemingly simple project may become a complicated one.

Close cooperation should be established and maintained with allied industries through the advisory council which should be continued with meetings at regular intervals. Industrial research at publicly supported institutions should be encouraged, and specific attention given to the study of the various construction materials and their proper use. The ultimate goal of the entire program should be, as previously stated, a better understanding of the requirements of farm structures and the adoption of standard recommended practices which will enable the American farmer to lower his production costs, preserve his products in a better marketable condition, and raise his standard of living.

SUMMARY

The inability of the farmer to conduct his own researches makes it necessary that any farm-structures research program be sponsored by publicly supported agencies such as the State experiment stations and the United States Department of Agriculture. Although a number of institutions are now doing some excellent work in this field, the total effort is relatively small and not commensurate with the importance of the problems. The purpose of this study has been primarily to analyze the reasons for lack of effective activity, and to suggest means for encouraging more and better research effort. Three reasons are assigned for the present situation, namely, a passive or secondary interest, problems of personnel, and lack of nation-wide correlation of effort.

From the many projects suggested a number of the more important ones have been compiled under appropriate headings.

During the past few years of agricultural readjustment, there has been a tendency to allow farm buildings to depreciate. Changes in agricultural management such as the increased use of machinery and the operation of larger farm units, marketing changes, and the necessity for farm and centralized storages, require corresponding changes in housing to maintain operating efficiency. Obsolescence and inadequacy, arising from improper planning and construction, are serious problems. A preliminary study has shown that although housing constitutes a minor factor among agricultural production

costs, it nevertheless exercises a major economic influence. Even at a time of agricultural depression a large amount of money is spent annually on farm construction. The wise investment of this money makes necessary the conduct of an adequate research program having as its objective the determination of basic requirements and methods of providing for them.

Few, if any, of the farm-structures problems are strictly local in importance or application. The political boundaries of the several States were not laid out according to farm-housing conditions. On the contrary, factors which necessitate variations in housing are regional. There are a number of problems the solution of which would have national application. This situation, together with the fact that farm structures have definite service requirements which call for careful research, justifies the pooling of interests and an attempt to improve, as well as to simplify, construction practice. A coordinated program gives promise of clarifying the whole farm-structures problem, of developing a closer relationship among the various research agencies, of decreasing unnecessary duplication of research effort, of increasing output from a given budget, and of developing standard practices for farm construction.

The distances that separate the workers in the different States, limitations on travel beyond their State boundaries, and the variety of group interests in housing problems, render impracticable the assuming of leadership by any one State. The United States Department of Agriculture alone is in a position to assume this leadership, and it should function not simply as another experiment station serving its local constituency, but as a national advisory and correlating agency. A close cooperative relationship in research activities should exist between the Federal organization, the State colleges, and industries manufacturing farm-building materials or equipment. A united effort will result in the advancement of research and the stimulation of resident teaching and extension. The formulation of a definite policy is the first step in carrying out this program. The Federal Department of Agriculture should accept the responsibility of leadership and work with the several States in making coordinated research a reality.

There are many problems common to industry and the State colleges. Industrial fellowships will help solve these with mutual benefit to both, and will assist in the training of much-needed personnel.

A study should be made of the various housing types, one of national importance being selected for first consideration. It should be analyzed carefully and the various research problems should be undertaken by the different experiment stations, according to their interests and facilities. Since cooperation will be entirely voluntary, actual procedure may vary from the logical. Definite organization is necessary, however, to assure growth. Many farm-structures problems are considerably involved and require the services of specialists in more than one line for adequate solution.

The farm-dwelling and the dairy-housing problems are recommended for first consideration.

A close relation with industrial, technical, and educational agencies should be maintained through direct contact with a permanent advisory council representing these interests, in order properly to interpret the specific needs of industry and of agriculture to the research agencies.

APPENDIX A.—OUTLINE FOR A COOPERATIVE RESEARCH PROJECT

Project No ____

---------- Experiment Station
Animal Husbandry Department
Physics Department
Agricultural Engineering Department

NAME: A study of glass substitutes.
LEADERS.
DATE SUGGESTED.
DATE APPROVED.
DATE BEGUN.
GENERAL OBJECTIVE:

To study the various glass substitutes on the market, with a view to ascertaining their value in connection with the housing of farm animals.

SPECIFIC OBJECTIVES:

A. To determine their ability to transmit ultra-violet rays (1) when new, (2) when dusty, (3) when aged.
B. To determine the life or probable period of usefulness, and the influence of (1) temperature of extremes, (2) light, (3) moisture, and (4) fatigue.
C. To determine the heat transmission.
D. To determine the effect on growth of animals.

METHOD OF PROCEDURE:

A. Laboratory set-up for measuring transmission of ultra-violet rays—
   1. Take 10 representative new samples from each material, selected from different lots; take 10 samples of ordinary window glass at random; make physical tests of transmission of ultra-violet rays.
   2. Study tendency of materials to accumulate a coating of dust, transmissibility when so coated, and readiness with which they may be cleaned satisfactorily—
      (*a*) Place specimens of each type in actual use in a poultry house.
      (*b*) At stated intervals remove a specimen and test transmissibility.
      (*c*) After test (*b*) is made, wash the materials and repeat the test.
      (*d*) Check results by repeating test, taking materials from the same original lot but which have been kept dust free in storage.

      This and (c) above when compared with the original tests will give data on the influence of age upon transmissibility.

B. Take representative samples and in turn—
   1. Expose to heat and observe temperature necessary to cause disintegration or deterioration. Repeat, exposing to cold.
   2. Subject to intense light to ascertain whether it exerts any deteriorating influence.
   3. Immerse in water, and at intervals observe (1) absorption, and (2) apparent effect upon material.
   4. Pliability. Make bending tests at various temperatures. Cut strips 2 inches wide from each specimen. Bend these respectively around a set of cylinders measuring respectively 2½, 2, 1½, 1, and ½ centimeters in diameter. Bend each strip parallel with itself through an arc of 180° at a uniform speed in exactly 2 seconds; the pliability is expressed alphabetically from *a* to *i* as follows—
      (*a*) Breaks on the 2½-centimeter cylinder.
      (*b*) Cracks the coating on the 2½-centimeter cylinder.
      (*c*) Cracks on 2-centimeter cylinder.
      (*d*) Cracks on 1½-centimeter cylinder.
      (*e*) Cracks on 1-centimeter cylinder.
      (*f*) Cracks on ½-centimeter cylinder.
      (*g*) Cracks when bent flat on itself (180°).
      (*h*) First bent in one direction, flat on itself, without cracking, then cracks when bent 360° in other direction.
      (*i*) First bent in one direction flat on itself, then in the other direction flat on itself without cracking.

C. Heat transmission.
1. Since relatively few colleges are equipped to make this test, cooperative arrangements should be made with one of these to secure this test.

D. Effect on growth of animals.
1. Using pens of equal size, cover each with a different substitute, one with glass having a transmissibility near the average as determined above, and one with screen wire only. These should be as large as can conveniently be arranged, to get observations on as many birds or animals as possible.
2. Select birds or small animals as nearly uniform as possible; place them in the pens provided; arrange for an equal exposure to sunlight in all pens; and observe (1) health, (2) vitality, and (3) rate of growth.

ORGANIZATION AND COOPERATION: The conduct of this project will be directed by a committee as follows:

————, representing the Department of Animal Husbandry, Chairman.
————, representing the Department of Physics.
————, representing the Department of Agricultural Engineering.

This committee shall meet at such times as is necessary and shall not only plan details but also supervise the conduct of the experiments.

In general, the responsibilities of the cooperating departments shall be as follows:

The Animal Husbandry Department will furnish the birds (animals), feed and care for them during the progress of the experiment, and make all observations of health, vitality, rate of growth, etc.

The Physics Department shall be responsible for all tests of the transmission of ultra-violet rays.

The Agricultural Engineering Department shall be responsible for the control technique necessary for all studies and make tests of the glass substitutes for—

a. Influence of heat, light, cold, and water.
b. Pliability.
c. Heat transmission.

HISTORY:

Since the value of the ultra-violet rays in animal raising has been appreciated only recently, the use of glass substitutes is relatively new. A number have been developed and are being offered for sale. Farmers have been told by the colleges of the value of the ultra-violet rays, but are unable to discriminate as to which of the substitutes will give satisfactory results. While some work has been done, it is incomplete and fragmentary and should be checked and developed further.

RECORDS OF PROGRESS:

Shall be filed with the director at regular intervals as desired by him.

FINANCIAL STATEMENT:

To conduct this project the following funds and resources will be needed:

Space requirements	$----------
Scientific assistance	----------
Labor	----------
Equipment	----------
Miscellaneous supplies	----------
Total	----------

BIBLIOGRAPHY:

APPENDIX B.—GENERAL OUTLINE FOR A RESEARCH PROJECT

Project No ----

---------- Experiment Station
Agricultural Engineering Department.

NAME: The design of a barn roof truss.

LEADERS.

DATE SUGGESTED.

DATE APPROVED.

DATE BEGUN.

GENERAL OBJECTIVE:

To study the barn roof truss to determine definitely the load that may be placed upon it; to analyze the present types of construction; and to promote simplified practice through the design of a truss which will meet the requirements as to loading, etc., as well as be economical of labor and materials.

SPECIFIC OBJECTIVES:

A. To determine the desirable mow capacity of a barn and the dimensions of a truss which will provide that capacity, according to—
   1. Number of animals housed per linear foot of barn.
   2. Feeding and bedding requirements per animal.

B. To analyze the loads that may be imposed upon the truss—
   1. Wind pressure—
      (*a*) Intensity.
      (*b*) Distribution.
   2. Snow.
   3. Hay.

C. To study present practice to find—
   1. How present designs meet or fail to meet actual load conditions.
   2. Economy of materials and labor.

D. To design a roof truss combining, as far as possible, the desirable characteristics as determined by the studies outlined above.

METHODS OF PROCEDURE:

A. Survey the present practice in hay storage, feeding requirements, etc., to determine mow space needed.

B. Select typical barns now in use representing various roof shapes, such as gambrel, gothic, and catenary; make a field study to ascertain where present construction has failed, and the reasons for failure.

C. Install necessary equipment and take observations of (1) wind velocity, (2) wind direction, and (3) pressures at various points on both windward and leeward sides of roof. In connection with this study the work of the stations where wind tunnels are now available should be carefully studied. Cooperation might be established with one of these stations for studies on models of barn roofs.

D. Design and construct suitable apparatus for testing full-sized barn sections, so arranged that loads may be applied in accordance with existing conditions as ascertained under B above.

E. Erect, in turn, full-sized specimens of barn frames of various types, keeping records of labor and material costs; apply such loads as might occur under operating conditions; test to destruction, and make observations regarding (1) distortion of frame, (2) load required to produce failure, and (3) cause of failure. (These sections should be at least 12 feet in length.) Analyze data accumulated and design modified truss incorporating the good points and avoiding the weaknesses as far as possible, of present types of construction.

ORGANIZATION AND COOPERATION.

HISTORY:

There is at the present time a lack of reliable information regarding the actual pressures exerted by the wind upon various types of structures. Work done in aeronautics leads us to believe that the figures which have been used are erroneous not only as to magnitude but also as to distribution. Rathbun (*24*), gives some interesting observations on the effect of wind on various-shaped objects. He says in part:

> A flat surface presents a resistant surface to an air current. A partial vacuum is created behind the surface. In this space, before the current again comes together, is an area in which the air is a complicated whirling mass. Contrary to common opinion, the pull caused by this whirling mass is far greater than the force of the current on the upstream surface. This partial vacuum force is from 60 to 75 per cent of the total force.
>
> The shape of an object has a great deal to do with the effective pressure of a wind current on it. Thus a flat circular disc will be affected about 12.7 times as much as a spherical based cone, base to the current, both having the same effective diameter. The effect on the flat disc is about 6.3 times as great as on a sphere of the same diameter.

Dryden and Hill (*11*) have reported some very interesting observations made on a parallelopiped 8 inches by 8 inches by 24 inches placed in a 10-foot wind tunnel. Their comment, however, is that there are little actual data available at the present time on wind pressures on the various shapes of structures. It is proposed that this investigation begin with observations on full-sized barns, and under actual weather conditions.

The present types of barn framing, like much of our architecture, have been a gradual development through the years. Much of it at least has been the result of trial and error method. Due to lack of knowledge of bolt and nail-holding capacities, variations in strength of ungraded timbers, etc., it is not possible under present conditions to make a thorough economical design of a wooden structure. The desirability of making tests on full-sized specimens has been recognized but, due largely to lack of funds, has not been carried out.

Our older barns were of timber construction. Heavy timbers as large as 16 by 16 inches were carefully mortised and fastened with oak pins. Some of the frames, in fact, were entirely of oak. While this type of framing had some desirable features, it also presented numerous difficulties. Timbers became scarcer as the source of lumber supply moved southward and westward. All rural lumber yards stock 2-inch and perhaps heavier material, but few carry the larger sizes so that the farmer often must pay a premium for larger sizes. Barns framed of heavy timbers are not economical of labor. Barn raisings were once common. After the frame was made and so far as possible assembled on the ground, a large group would congregate and raise it. The hay mow of the full-framed barn is obstructed with posts, beams, and braces, and is unsuited to modern barn operations.

These are a few of the reasons for the development of the present types of barn framing. Several distinct types are now in common use. Many variations of each can be observed in the building plans from the various colleges and those sent out by the equipment companies. Most of these use no material thicker than 2 inches.

A good mathematical analysis of the Shawver truss is given by Strahan (*28*), (pp. 59–68).

Another type of gambrel roof construction is the wing joist or braced rafter. This differs from the Shawver in that each rafter is a truss in itself rather than having a heavier one at intervals of 12 or 14 feet. A preliminary study of recommendations by various sources shows a large number of variations. These, upon observation, will be found to differ materially, not only in the sizes of material used but also in the arrangement of braces. Obviously all of these are not ideally arranged to give a maximum of strength considering economy of material and labor.

The inability to provide effective joints has proven a difficulty in the framing of wooden buildings.

Of late there seems to be a growing demand for the curved or gothic roof. Notwithstanding its greater cost and the fact that many settle out of shape in a short time, there seems to be an element of appeal in the curved roof. Several methods of construction are now being practiced.

About 1913 the Iowa station started the development of a curved masonry roof. This roof is carefully treated in a thesis written by Bruce Russell. (*25*) One of the unique features of this roof is the curve used in its construction. The inverted catenary was found to approximate very closely the ideal condition; that is, the resultant of the dead loads passes through the middle third of the arch ring, and all stresses are compressive.

One of the shortcomings of the gothic type of roof is that the arch ring is outside of the resultant of dead loads. This places a bending stress on the arch at all times. The catenary curve has been suggested as an improvement of the curved roof in wood construction. While it may be somewhat difficult to lay out, the difficulty is believed to be easily surmountable and the curve offers definite advantages in (1) use of small sizes and short lengths of lumber, (2) a minimum of sawing and cutting, (3) ease of erection and economy of labor, and (4) stability and strength.

APPENDIX C.—DIVISION OF FUNDS FOR AGRICULTURAL ENGINEERING RESEARCH BY TYPE OF INVESTIGATION, JULY 1, 1929, TO JUNE 30, 1930

State	Rural electrification			Farm operating equipment			Buildings, water supply, etc.			Drainage, terracing, etc.			Irrigation		
	Men employed	Equivalent full time	Funds	Men employed	Equivalent full time	Funds	Men employed	Equivalent full time	Funds	Men employed	Equivalent full time	Funds	Men employed	Equivalent full time	Funds
			Dollars			Dollars			Dollars			Dollars			Dollars
Alabama [1]															
Arizona				1	0.25	750							2	2.00	11,050
Arkansas				1	.25	900	1	0.12	600				1	.50	2,500
California	3	1.6	10,000	8	4.20	18,775	3	.97	4,125						
Colorado [2]															Z
Connecticut	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Florida [2]															
Georgia	1	.25	2,000	1	.50	1,450	1	.17	750	1	0.08	300			
Idaho	2	1.00	3,280	2	.50	2,357	1	.50	1,157	1	.50	745	1	.50	1,360
Illinois	2	.08	300	4	1.88	9,926	2	.50	2,500	2	.33	500			
Indiana [1]	1	1.00		2	1.75		1	.50		1	.50				
Iowa	1	.10	500	3	1.50	8,030	2	1.50	5,000	1	.25	1,800			
Kansas	2	1.00	4,350	2	.50	2,600	2	1.00	3,100						
Kentucky	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(2)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
Louisiana				2	1.00	11,800									
Maine [2]															
Maryland	2	.75	3,100												
Massachusetts				1	.38	2,275	1	.38	2,000						
Michigan	2	.50	3,000	1	.50	3,000	1	.50	3,000	1	.25	2,500			
Minnesota [1]				3	1.00		4	.50		11	6.00				
Mississippi				1	1.00	6,300									
Missouri	1	1.00	5,000	1	.50	1,800	1	.20	500			150			
Montana [2]															
Nebraska	3	1.50	4,700	4	2.00	8,320	1	.50	1,000						
Nevada [2]															
New Hampshire	2	1.50	6,195												
New Jersey	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
New Mexico													2	2	5,750
New York	3	.50	2,050	2	.20	615	1	.30	1,150						
North Carolina						100									
North Dakota				2	.75	3,200	1	.25	1,130						
Ohio	1	1.00	5,000	4	2.00	11,750	1	.25	1,500	1	.25	1,750			
Oklahoma										1	.50	2,400			
Oregon [2]															
Pennsylvania	1	1.00	4,090	2	2.00	7,030									

South Carolina	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)	(3)
South Dakota				2	.60	3,000	2	.50	3,133							
Tennessee [2]																
Texas [1]	1	1.00		1	1.00											
Utah										2	.75	6,300	2	.58	2,200	
Virginia	1	.25	500	1	1.00	3,500	1	.50	500	1	.25	500				
Washington	2	1.18	6,000													
West Virginia				1	.12	550	1	.13	550							
Wisconsin	1	1.00	3,000	2	1.50	11,065	3	1.50	8,600	2	1.00	6,810				
Wyoming [2]																

[1] Funds not segregated according to type of work. [2] No report received. [3] No funds.

APPENDIX D.—DISTRIBUTION OF FUNDS AND PERSONNEL FOR AGRICULTURAL ENGINEERING RESEARCH IN THE UNITED STATES FOR THE YEAR JULY 1, 1929, TO JUNE 30, 1930

State	Source of funds					Men employed	Equivalent full-time men	Division of funds		Is research increasing or decreasing?	
	Agricultural experiment station	Engineering experiment station	Institutional	Private	Total			Salaries	Project maintenance	Mechanical farm equipment	Farm structures
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*			*Dollars*	*Dollars*		
Alabama	5,600			6,000	11,600	6	4.00	7,600	4,000	(1)	(1)
Arizona	11,800				11,800	3	2.25	8,843	2,957	Increasing	(2)
Arkansas	300		3,700		4,000	3	.88	2,700	1,300	do	No change.
California	25,475			7,400	32,875	14	6.90	21,175	11,700	No change	Increasing.
Colorado [1]											
Connecticut	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Florida [1]											
Georgia			2,500	2,000	4,500	1	1.00	1,800	2,700	Increasing	(2)
Idaho	5,620			3,279	8,899	5	3.00	4,435	4,464	do	Increasing.
Illinois	11,326		1,900		13.226	6	2.83	9,776	3,450	do	No change.
Indiana	6,000				6,000	2	1.50	4,200	1,800	do	Decreasing.
Iowa	10,900	2,300	1,590	540	15,330	7	3.35	8,790	6,540	do	No change.
Kansas	1,500	5,550		3,000	10,050	4	2.50	5,750	4,300	No change	Increasing.
Kentucky	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
Louisiana	9,700		2,100		11.800	2	1.00	4,000	7,800	Increasing	(2)
Maine [1]											
Maryland	600			2,500	3,100	2	.75	1,600	1,500	Increasing	(2)
Massachusetts	4,275				4,275	1	.75	3,375	900	do	(2)

[1] No report. [2] No funds.

APPENDIX D.—DISTRIBUTION OF FUNDS AND PERSONNEL FOR AGRICULTURAL ENGINEERING RESEARCH IN THE UNITED STATES FOR THE YEAR JULY 1, 1929, TO JUNE 30, 1930—Continued

State	Source of funds					Men employed	Equivalent full-time men	Division of funds		Is research increasing or decreasing?	
	Agricultural experiment station	Engineering experiment station	Institutional	Private	Total			Salaries	Project maintenance	Mechanical farm equipment	Farm structures
	Dollars	*Dollars*	*Dollars*	*Dollars*	*Dollars*			*Dollars*	*Dollars*		
Michigan	11,000	500			11,500	5	1.83	5,500	6,000	do	Increasing.
Minnesota	13,684		4,268		17,952	19	7.50	14,364	3,588	do	Do.
Mississippi	6,300				6,300	1	1.00	2,750	3,550	do	(2)
Missouri	3,900	1,000		5,000	9,900	2	1.50	5,300	4,600	do	Increasing.
Montana [1]											
Nebraska	11,520	2,500			14,020	8	4.00	10,220	3,800	No change	No change.
Nevada [1]											
New Hampshire	6,195				6,195	2	1.50	4,228	1,967	Increasing	
New Jersey	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
New Mexico	5,250		500		5,750	2	2.00	3,200	2,550	(1)	(1)
New York			3,815		3,815	4	1.00	3,240	575	Decreasing	Decreasing.
North Carolina	100				100				100	Increasing	(2)
North Dakota	4,330				4,330	2	1.00	3,330	1,000	do	Increasing.
Ohio	15,000			5,000	20,000	7	3.50	13,075	6,925	do	No change.
Oklahoma	2,400				2,400	1	.50	900	1,500	(1)	(1)
Oregon [1]											
Pennsylvania	10,630			490	11,120	3	3.00	8,320	2,800	Increasing	(2)
South Carolina	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)	(2)
South Dakota	6,133				6,133	3	1.12	3,233	2,900	(1)	(1)
Tennessee [1]											
Texas	4,900		200	8,200	13,300	2	2.00	4,900	8,400	Increasing	Increasing.
Utah	8,500				8,500	3	1.33	4,500	4,000		(2)
Virginia	3,500	500	500	500	5,000	6	2.00	3,500	1,500	Increasing	Increasing.
Washington				6,000	6,000	2	1.17	3,967	2,033	(1)	(1)
West Virginia	1,100				1,100	1	.25	900	200	(1)	(1)
Wisconsin			26,475	3,000	29,475	8	5.00	18,895	10,580	No change	Increasing.
Wyoming [1]											

[1] No report.

[2] No funds.

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[1] Representatives nominated by organizations and appointed by Secretary of Agriculture, August, 1929.
[2] Died, Nov. 11, 1929.